Geology of the Central Santa Ynez Mountains, Santa Barbara County, California

BULLETIN 186

California Division of
Mines and Geology

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By T. W. DIBBLEE, Jr.

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ILLUSTRATIONS

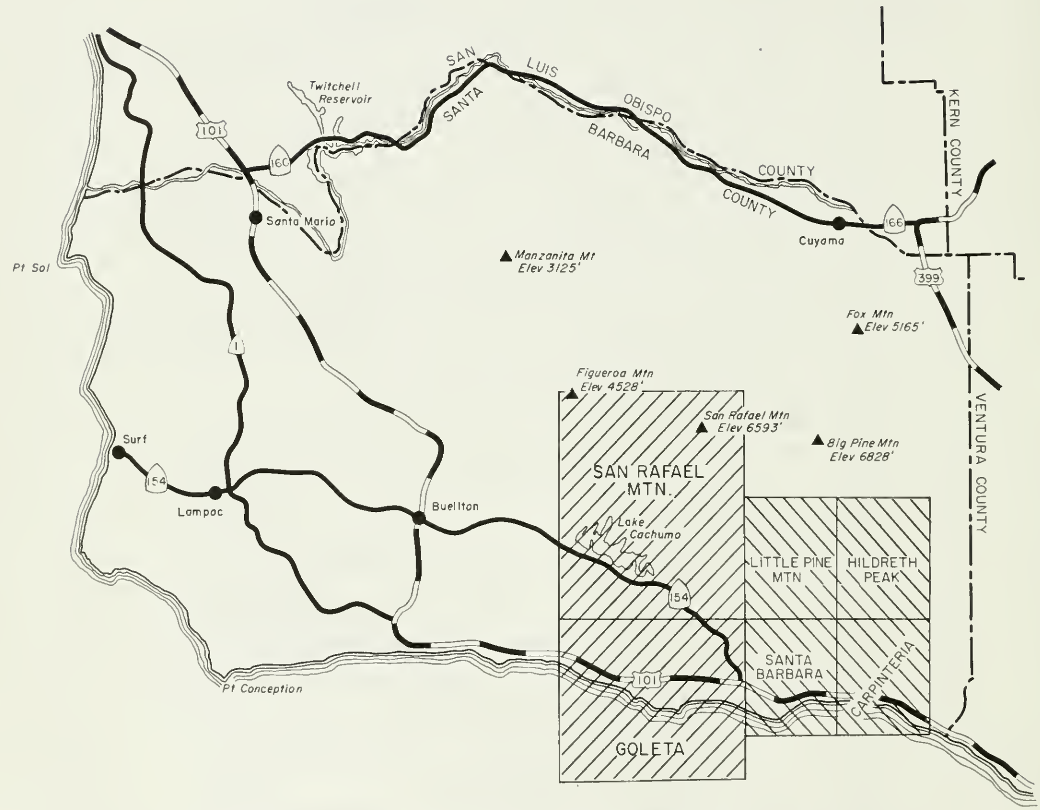

Figure 1. Index map of Santa Barbara County, California, showing the location of the six quadrangles described in this report.

ABSTRACT

The area mapped includes the central sector of the east-trending Santa Ynez Range of mountains and adjacent coastal strip to the south in the vicinity of Santa Barbara, and parts of the adjacent Santa Ynez River area and of the northwest-trending San Rafael Mountains to the north.

The oldest stratigraphic unit is the Franciscan Formation of probable Late Jurassic or Early Cretaceous age in this area—a great thickness of intensely sheared dark sandstone and shale with lenses of chert and bodies of basic igneous rocks altered to greenstone and serpentine.

Above the Franciscan Formation is a very thick sequence of marine shales and sandstones of Cretaceous age. In the San Rafael Mountains and Santa Ynez River area these are divided into three units as follows from the lowest upward: Espada Formation, as thick as 16,000 feet, unnamed shale, as thick as 4,000 feet, and unnamed sandstone, as thick as 9,000 feet. In the Santa Ynez Range only 2,000 feet of the top of the sequence is exposed and is mapped as the Jalama Formation.

Lying above the strata of Cretaceous age, in places unconformably, is a sequence about 9,000 feet thick of marine shales and sandstones of early to late Eocene age divided into the following units in ascending order: Sierra Blanca Limestone (present only locally); Juncal and Anita Formations; Matilija Sandstone; Cozy Dell Shale; Sacate Formation, and "Coldwater" Sandstone.

In the Santa Ynez Range the marine strata of Eocene age are overlain by the terrestrial Sespe Formation of probable Oligocene age, about 3,000 feet thick. On the south slope of the range the basal Sespe beds grade laterally westward into littoral marine sandstones of the Gaviota Formation. The Sespe Formation is in turn overlain by the marine Vaqueros Sandstone and Rincon Shale, both of lower Miocene age and totaling about 2,000 feet in thickness. All these formations are absent in areas north of the Santa Ynez River.

The middle and upper Miocene is represented by the marine Monterey Shale and overlying Sisquoc Formation (shale and diatomite) on both sides of the Santa Ynez Range. North of the Santa Ynez fault the "Temblor" Sandstone occurs at the base of the Monterey Shale and rests unconformably on formations ranging from Rincon to Franciscan, with increasing angular discordance northward. In the Santa Ynez River area the Sisquoc Formation grades laterally eastward into the Tequepis Sandstone. The middle and upper Miocene formations total about 4,500 feet in thickness.

The Pliocene is represented by the "Pico" Formation south of the Santa Ynez Range and by the Careaga Sandstone north of it. Both are marine, of upper Pliocene age, and rest unconformably on Miocene formations. South of the range the shallow-water marine Santa Barbara Formation, mainly of lower Pleistocene age, also rests with great angular discordance on Miocene and older formations; its non-marine facies is known as the Casitas Formation. North of the range the Careaga Sandstone is overlain by the non-marine Paso Robles Formation of Plio-Pleistocene age. The Plio-Pleistocene sequence on both sides of the Santa Ynez Range totals about 3,000 feet in thickness.

Several hundred feet of upper Pleistocene fanglomerate and older alluvium lies on the eroded surface of all older formations on both sides of the Santa Ynez Range.

Within the district are parts of three major structural blocks separated by the Santa Ynez and Little Pine faults, the dominant structural breaks within the district which were active during Quaternary time.

The Santa Ynez fault is a south-dipping reverse fault along which the Santa Ynez Mountain block was elevated and tilted southward. The structure of the Santa Ynez Range and adjacent coastal area is essentially homoclinal with a southerly dip toward the Santa Barbara Channel, in formations ranging in age from Cretaceous to upper Miocene. In one part of the range is a sheared mass of Franciscan rocks squeezed up adjacent to the Santa Ynez fault; the homoclinal structure south of this mass is overturned southward. In another part the strata are compressed into several folds with axes trending north of west diagonally into the Santa Ynez fault. On the coastal area are several steep faults trending west to north of west, and several folds with axes of similar trends.

The Little Pine fault is a northeast-dipping reverse fault along which the segment of the San Rafael Mountain block within the northeastern part of the district was elevated. This mountain block exposes Franciscan rocks adjacent to the fault, and these are overlain by the enormous thickness of Cretaceous and Eocene sediments which are compressed into several large folds with axes trending north of west and plunging southeast.

Between these two elevated mountain blocks is a wedge-shaped block whose structure is synclinal in formations ranging from Eocene to Pleistocene, but within it are several minor faults, and locally many minor folds that become increasingly compressed southeastward as this wedge narrows between the converging mountain blocks. All structures in this wedge-block trend north of west.

It is concluded that the structural features of the area evolved as the result of a severe compressive stress, but which may be subsidiary to one or more rotational stresses active at great depth, as suggested from evidence of lateral components of movement on some of the faults.

The physiographic features within the district are all very young and are the direct result of crustal movements during the Quaternary period, mostly during late Pleistocene time.

Mineral resources of economic value are chiefly petroleum and natural gas. Within the district is one major producing oil field, one gas field, and three small oil fields that are now abandoned. All these fields are on or near the coast. Other resources are small deposits of quicksilver that were mined near the Santa Ynez River.

Geology of the Central Santa Ynez Mountains, Santa Barbara County, California[1]

By T. W. Dibblee, Jr.[2]

INTRODUCTION

Location and method of work. The area mapped embraces about 350 square miles of the southeastern part of Santa Barbara County, and includes the city of Santa Barbara on the coast.

The geology of the area was mapped by the writer at various times during the years 1931 to 1938 and in 1952, 1963, and 1964. The geology has now been plotted on all or parts of the following topographic quadrangle maps issued in 1943 and 1944 by the U.S. Army Corps of Engineers: 15-minute, 1:62,500 scale Goleta and San Rafael Mountain quadrangles; 7½-minute 1:31,680 scale Santa Barbara, Carpinteria, Little Pine Mountain and Hildreth Peak quadrangles.

The geology of the Santa Ynez Mountain range was mapped by the writer. The geology of the coastal area and of the Santa Ynez River area was taken from various published sources mentioned below, modified and field-checked by the writer. The geology of the north half of the San Rafael Mountain quadrangle was mapped mostly in 1963 and 1964, after this report was written, so the geology of this area is not described in detail.

For kind cooperation and permission to publish the depths of formational contacts encountered in many of the exploratory test holes herein listed in search for oil or gas within the area, the writer is greatly indebted to the various oil companies that drilled these holes. The accompanying cross sections through the area are in part based on the data from these exploratory holes.

This work is a stratigraphic, structural and geomorphic study of the central sector of the east-trending Santa Ynez Mountain range and its relationships to the adjacent geologic and physiographic features to the south and north. The work is an eastward continuation of the geologic study of the western sector of the Santa Ynez Mountains (Dibblee, 1950).

Previous work. No detailed geologic map of the entire area has been published, although several geologic maps and descriptions of parts of it have appeared, as well as small scale compilation maps covering most or all of it. Omitting many early geologic notations, the first important report was by Fairbanks (1894, pp. 501–507). The first geologic map of part of the area was by R. Arnold (1907) which covers the coastal plain and the south slope of the Santa Ynez range east of Santa Barbara. The earliest geologic map of part of the Santa Ynez river valley within the mapped area was by W. S. W. Kew (1919). Six years later appeared a comprehensive map and report of a large part of the Santa Ynez river drainage basin covering the southern third of the 30-minute 1:125,000-scale Santa Ynez quadrangle by R. N. Nelson (1925).

An excellent summary of the geology of the San Rafael and Santa Ynez Mountains with small scale map is given by R. D. Reed and J. S. Hollister (1938, pp. 86–97).

The geology of the northeastern part of the area was mapped and described in detail by B. M. Page, J. G. Marks and G. W. Walker and geology students of Stanford University (1951). During the same field season this mapping was extended northwesterly by G. W. Walker (1950).

California Division of Mines Bulletin 170 (1954) *Geology of southern California* contains a geologic map of the coastal area east of Santa Barbara by R. Lian (Map sheet 25). This bulletin also contains a small-scale geologic map of the Transverse Ranges that includes the mapped area, as compiled by T. L. Bailey (Chap. II, contr. 3, pl. 4). The geology shown on the preliminary California State geologic map (Los Angeles sheet, 1954) was taken largely from the writer's mapping for the area under discussion.

Papers that deal with the faults of the coastal area include one by Bailey Willis (1925), and another by M. L. Hill (1932).

Papers that deal with the stratigraphy of the Tertiary rocks within the area include one by T. L. Bailey (1947, pp. 1913–35) which describes the Sespe red beds, as well as the adjacent Eocene and lower Miocene formations of the Ventura basin. R. M. Klein-

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[1] Submitted for publication, 1957.
[2] Presently, U.S. Geological Survey, Menlo Park, California.

pell (1938) briefly describes some of the Miocene formations in parts of the area.

The geology of the oil and gas fields within the area on and near the coast are described in California Division of Mines Bulletin 118 (1938, pp. 377–386), and in several other earlier publications.

The ground-water resources and related geology of the coastal plain are described by J. E. Upson (1951).

Settlements, accessibility and industry. Santa Barbara, a city with a population of about 70,000, occupies a large part of the coastal plain and is expanding. Suburban towns on the coastal plain to the west are Goleta, population about 3000; and to the east, Montecito, population about 2000; Summerland, about 500; and Carpinteria, about 2000.

The area is accessible by many roads on the coastal plain, and a highway over the mountains via San Marcos Pass into the Santa Ynez River area. The mountains are accessible by U.S. Forest Service roads and foot trails.

The fertile lands of the coastal plain are cultivated and irrigated, dotted with walnut and lemon groves, with some acres devoted to vegetables. The grassy foothills of the coastal plain and in the Santa Ynez River area are used for pasturage of dairy and beef cattle.

The rugged, brush covered mountain areas are largely part of the Los Padres National Forest and are watershed areas for two reservoirs, Gibraltar and Cachuma lakes, that supply water to the coastal plain.

Climate. The climate of the coastal area is mild throughout the year, with marine fog prevalent during summer nights. In the mountains and lowlands to the north summers are hot and dry, with daytime temperatures reaching 90 to 105 degrees; winters are mild but night temperatures often fall below freezing in inland valleys and canyons.

Nearly all precipitation falls from Pacific storms that pass over the area any time from October to May, but mainly during the winter months. In Santa Barbara an 89-year average annual rainfall was 17.9 inches, which is general for the coastal lowlands. Precipitation is about the same in the lowlands north of the Santa Ynez Range. Precipitation over the mountain range itself is higher, increasing with altitude, and is estimated by Upson (1951, p. 33) to be as much as 35 inches annually over the higher parts of its crest.

Vegetation. The natural vegetation of the area is determined by three main factors. These are 1) character of underlying rock formation; 2) amount of residual soil; 3) direction and steepness of slope, and 4) elevation.

On the coastal area, and in the Santa Ynez Valley area, claystone and soft shale formations weather to a loamy soil that supports only grasses and annual herbs. Hard shale formations, and gravels and sands with a clayey matrix support low sage brush. The mountains are underlain predominantly by sandstone and hard shale beds that form little soil, and are consequently covered by dense chaparral brush. This is especially impregnable on steep, north-facing slopes. It is composed of many shrubs, of which scrub oak and mountain lilac *(Ceanothus)* predominate. On some north slopes above 3500 feet are groves of pine and fir. Practically all canyons throughout the mountains, and some of the lower north slopes, are covered with oak and laurel trees. The Santa Ynez River is lined with cottonwood, birch, sycamore and oak trees. Streams that traverse the coastal plain have willow thickets along their margins.

Physical features. The district mapped includes parts of four main physiographic regions of Santa Barbara County. From south to north these are: 1) Coastal plain, 2) Santa Ynez Mountain range, 3) Santa Ynez Valley, and 4) San Rafael Mountains. These features are shown on figure 2, and described under the heading "Geomorphology."

The coastal plain fronting the Santa Barbara Channel between the coast line and the Santa Ynez Mountains toward which it rises is roughly 5 miles wide, and includes several local alluvial plains or valleys. From west to east these are: 1) Goleta Valley, 2) Santa Barbara and Montecito plain, and 3) Carpinteria Valley. These local plains, together with the hills or mesas that separate or bound them, are described under "Geomorphology."

The Santa Ynez Mountains form a narrow continuous range parallel to the coast, and is the most westerly range of the east-trending Transverse Ranges of southern California. The area north of the Santa Ynez Mountains is one of low hills in the east end of the Santa Ynez Valley through which the Santa Ynez River flows westward. Southeastward the hills of this lowland area increase in relief and the upper Santa Ynez River emerges through a narrow canyon. The mountainous and semi-mountainous area north of the Santa Ynez River lowland area is the southern part of the San Rafael Mountains, the southernmost of the northwest-trending Coast Ranges of California.

STRATIGRAPHY

The Santa Ynez mountains and adjacent lowlands are composed almost entirely of sedimentary rocks ranging in age from Late Jurassic (?) to Recent. The Jurassic (?) is represented by the Franciscan formation the oldest unit in the district and the only one in which igneous rocks occur, mostly basic intrusives.

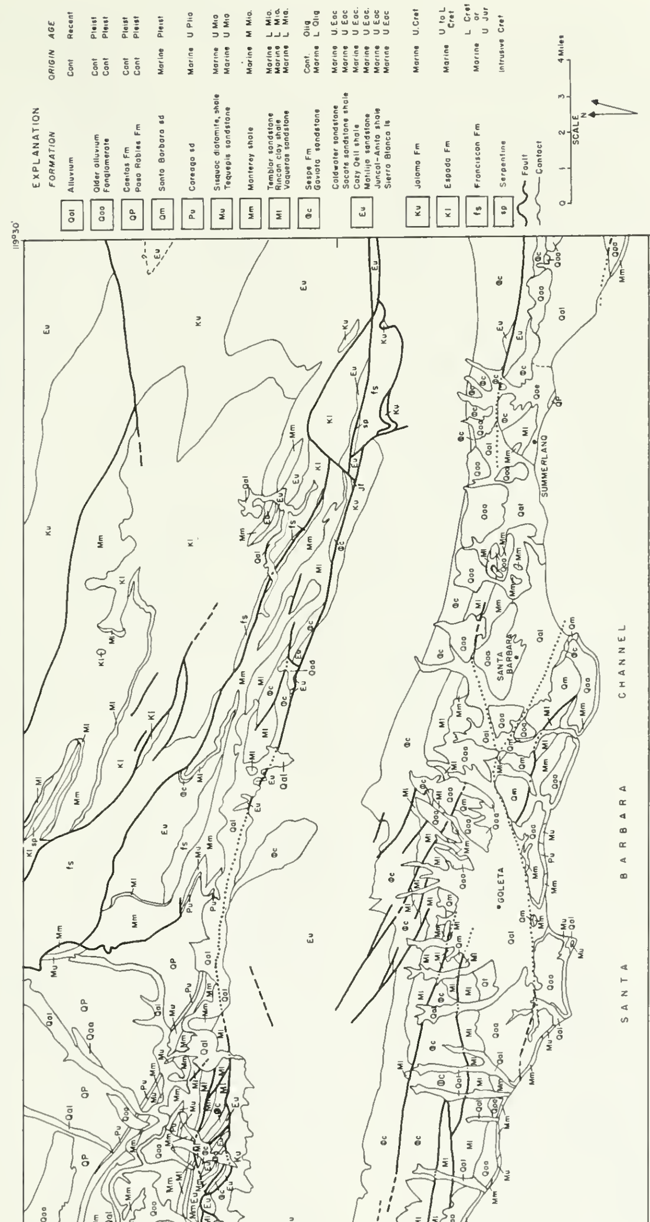


Figure 2. Areal map showing generalized geology of central Santa Ynez Mountains, Santa Barbara County, California.

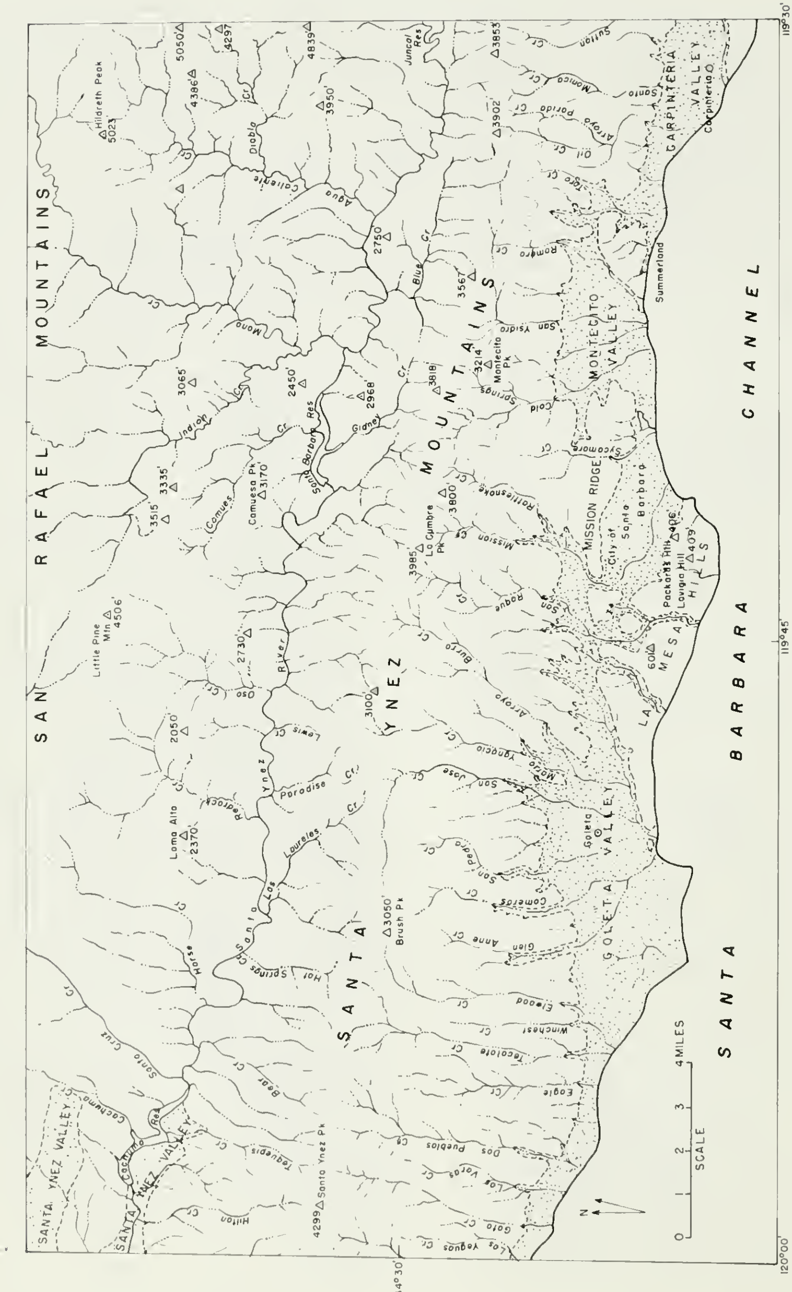


Figure 3. Physiographic map of the central Santa Ynez Mountains and vicinity, Santa Barbara County, California.

The Cretaceous and Eocene are represented by great thicknesses of clastic marine sediments. These are overlain by terrestial and marine clastics of Oligocene—Early Miocene age. The Middle and Late Miocene and Early Pliocene (?) are represented largely by siliceous organic marine sediments. There are apparently no sediments of Middle Pliocene age in the area, but the Late Pliocene and Pleistocene are represented by shallow marine and terrestial clastic sediments.

The Santa Ynez fault at the northern base of the Santa Ynez Range separates two structural blocks in which the stratigraphic succession of each differs.

In the southern block, which includes the Santa Ynez Range and coastal plain, the exposed stratigraphic succession from Upper Cretaceous to Upper Miocene is practically continuous, with a thickness totaling some 24,000 feet, and is fairly consistent. This succession is overlain unconformably by Upper Pliocene (?)-Pleistocene sediments that reach a maximum buried thickness of about 3,000 feet.

In the northern block, which includes the Santa Ynez River area, the stratigraphic succession from Cretaceous to Upper Miocene is interrupted by at least two regional unconformities and is characterized by drastic lateral changes of facies and thicknesses. The succession includes a 20,000-foot-thick series of Cretaceous strata, overlain unconformably by a 7,000-foot Eocene sequence. These are in turn overlain unconformably by about 4,000 feet of Miocene strata. Another major unconformity separates these from the Upper Pliocene-Pleistocene strata that total roughly 3,000 feet.

Franciscan Formation

Distribution. The Franciscan Formation, the oldest unit exposed in the San Rafael and Santa Ynez mountains, crops out in three places within the map area. The longest exposure is on the southwestern slope of the San Rafael Mountains. Two miles south of this exposure the Franciscan rocks again crop out as a band half a mile wide between lower Oso and Redrock Canyons. In the Santa Ynez Range there is only one exposure of the Franciscan Formation, which is on the north slope south of Blue Canyon. This exposure, mapped and described by Page, Marks and Walker (1951, fig. 2, pp. 1732–4) is the most southeasterly exposure of the Franciscan Formation in the Coast Ranges of California.

Topographic expression. The topography formed by the Franciscan Formation is more varied than that of any other unit, owing to the presence of so many rock types. In the San Rafael Mountains the Franciscan forms generally rolling, grass-covered slopes interspersed with steeper brush-covered hills, with dark brown rocky knobs and green, shiny, slickensided outcrops of serpentine. The grass-covered slopes are generally formed by shale, which rarely crops out but weathers to a soft gummy adobe soil that supports grass. The brush-covered hills are formed mainly from exposure of sandstone. The dark rocky knobs, with little or no vegetation, are eroded from greenstone. Serpentine forms the characteristic green shiny exposures, and supports practically no vegetation. Landslides are numerous in the Franciscan, especially in areas of shale and serpentine.

In lower Oso and Redrock Canyons the Franciscan forms grass-covered and brush-covered hills. In the Santa Ynez mountains the Franciscan is eroded to generally low relief, and with the exception of the serpentine exposure in Blue Canyon, it is all brush-covered.

General character. The Franciscan Formation that crops out within the map area is typical of that exposed northwesterly in the Coast Ranges. It is composed of sedimentary rocks that are not metamorphosed but are severely deformed and sheared, and intruded by basic igneous rocks largely altered to greenstone and serpentine.

The sedimentary rocks of the Franciscan are unfossiliferous and are composed mainly of dark colored arkosic sandstones or graywacke, clay shale, and occasional lentils of varicolored chert.

The basic igneous rocks now altered to greenstone and serpentine are commonly regarded as part of the Franciscan (Nelson, 1925, p. 338, map) because they are so intricately associated with it. However this is a matter of personal opinion, as some geologists do not regard them as part of the Franciscan because they are intrusive into it. Glaucophane schist occurs as an occasional small outcrop, too small to map, associated with the basic meta-igneous rocks in the Franciscan.

Shale. The shale of the Franciscan is greenish-gray and is argillaceous to sandy. It is moderately hard but crumbly, and in most places is so severely sheared and fractured that its original bedding is destroyed. As a result it is deeply weathered and rarely crops out except where it is exposed in steep banks or in the cirques of landslides. It commonly contains dark gray calcareous concretions, up to a foot in longest dimension, that weather cream-white on the surface.

There are all gradations from argillaceous shale through siltstone into sandstone. Some of the siltstone is micaceous and moderately bedded. In places where the shale is not severely sheared, it is bedded and difficult to distinguish from the bedded shale of the over-

lying Espada Formation. In the east fork of upper Oso Canyon, just north of the Little Pine fault, the shale within 1,000 feet of the fault is prominently bedded and quite similar to that of the Espada Formation.

Sandstone. The sandstone of the Franciscan, or graywacke, as described by Davis (1918), is arkosic, dark greenish-gray when fresh, but weathers greenish-brown. It is hard, fine grained, and is composed of subangular grains of quartz and feldspar in varying proportions, together with minute dark grains and minute flakes of biotite. The grains are closely packed to form a solid mass practically devoid of any pore space. The sandstone is closely fractured so that it does not form prominent outcrops. The sandstone of the Franciscan is similar to those of the overlying Espada Formation, but differ in its massiveness and lack of bedding, lack of carbonaceous fragments, and prevailing greenish color. The sandstone occurs as lenticular bodies as thick as several hundred feet, or as small drawn-out pod-like masses only a few feet thick enclosed in sheared shale.

At several places in the San Rafael Mountains the sandstone contains small pebbles of black chert and andesitic igneous rocks. Pebble conglomerates occur rarely in the Franciscan of that area.

Chert. In lower Oso Canyon varicolored chert occurs as a prominent lentil as thick as 50 feet within the Franciscan sandstone and shale. It extends westward about 2 miles and becomes overlapped by Tertiary rocks. In Redrock Canyon another similar lentil of chert appears stratigraphically higher in the section. In both these lentils the chert occurs as layers one-half to four inches thick separated by partings of thinly laminated shale. The chert is very hard and brittle. It is crudely banded to massive, and is of various colors, mostly dark brownish-red, pale green or cream-white, or mixtures of one or several colors. The chert layers are nearly everywhere undulating, in places contorted and fractured. These cherts are similar to those described in detail by Davis (1918).

Besides these layered outcrops of chert, very small short lentils of similar varicolored chert occur in the Franciscan in the San Rafael Mountains, and in the Santa Ynez mountains south of Blue Canyon.

Greenstone. In the San Rafael Mountains, greenstone, a rock formed by probable alteration of basalt or other fine-grained basic igneous rock, occurs as small pod-like masses commonly, though not everywhere, associated with serpentine in the sedimentary rocks of the Franciscan. Small masses of greenstone are present in the Franciscan of the Santa Ynez Mountains east of Romero Saddle.

The greenstone is typical of that occurring through the Franciscan of the Coast Ranges. This rock is massive, closely jointed, and breaks with irregular fracture. While the rock is not extremely hard, it is strongly coherent so that it crops out as protruding masses within the less resistant rocks of the Franciscan. The rock is greenish-black but weathers dark greenish-brown, or even reddish-brown. The rock is of such fine texture and is so thoroughly altered that its constituent minerals are difficult to determine with a hand lens. The dark greenish-brown color indicates the presence of abundant iron oxides, probably limonite and hematite that resulted from alteration of iron-bearing silicate minerals. The original basic igneous rock from which the greenstone was altered was supposedly olivine basalt or fine-grained diabase.

Some masses of greenstone appear to be intrusive plugs within the Franciscan sedimentary rocks, but others are lenses in accordant relationship with them and these may be extrusive flows.

Serpentine. In the San Rafael Mountains serpentine occurs as several sill-like masses in the Franciscan Formation. These masses are generally vertical and trend north or west, parallel to the strike of the Franciscan rocks, and are as thick as 1,000 feet and traceable for as much as a mile or more. Serpentine is also present on the north side of the Little Pine fault in the vicinity of the Gibraltar Reservoir. A large mass of serpentine occurs between and in the Santa Ynez fault zone in Blue Canyon. None was found in the Franciscan south of Blue Canyon, nor in lower Oso and Redrock Canyons.

The serpentine is a massive greenish-black to light bluish-green rock composed almost entirely of the hydrous magnesium silicate mineral antigorite. Very little remains of the original rock from which the serpentine was formed, except in some exposures where serpentine contains residual anhedral crystals of pyroxene. The rock is commonly cut by thin fibrous veinlets of asbestos less than two millimeters wide. Nearly everywhere the serpentine is sheared, with numerous shiny slickensided surfaces so that the rock weathers to shiny lenticular and ovate fragments.

The serpentine was formed by alteration of a coarse-grained basic intrusive igneous rock, such as peridotite or pyroxenite. This is indicated by the presence of scattered residual crystals of pyroxene in some outcrops of serpentine. The original basic igneous rock was apparently hydrothermally altered to serpentine at depth, and during this process the rock expanded, as indicated by the numerous slickensides present throughout the serpentine. This expansion may have also caused much of the shearing now seen in the enclosing shale and sandstone.

In some places, especially along the Little Pine fault near the Gibraltar Reservoir, the serpentine itself is partly to completely altered to silica—carbonate rock. At the surface the more soluble constituents are leached out, leaving a cavernous irregular mass of spongy, brown limonite, honeycombed with veinlets of secondary silica and calcite.

Glaucophane schist. In the San Rafael Mountains contorted glaucophane schist occurs as an occasional small pod a few feet long. Near Romero Saddle in the Santa Ynez mountain exposure is a prominent outcrop of this rock. The rock is conspicuous because of its deep blue color. It is fine to medium crystalline, with contorted schistosity, hard and compact. It is composed of the blue soda—amphibole mineral, glaucophane, and minor admixtures of lawsonite(?), chlorite, and muscovite. The glaucophane occurs as parallel minute prismatic crystals that impart a linear texture to the rock. The other minerals mentioned occur as minute flakes parallel to the schistosity of the rock.

The origin and genesis of this rock are not definitely known. The rock apparently formed from deposition of soda-amphibole and associated minerals under conditions not yet determined.

Stratigraphy. Only partial sections of the Franciscan Formation crop out within the map area. At no place is the base exposed, and it is either in fault contact or in unconformable relationships with the overlying formations. Its relationship to the overlying Espada Formation, where it is not in fault contact with it, is obscured by serpentinous intrusions and is otherwise not certain, but in places the relationship appears to be depositioned or even gradational.

In the San Rafael Mountains the Franciscan Formation is so severely sheared and brecciated that it is not possible to decipher the stratigraphic sequence. It is composed of massive shattered sandstone and intercalated lenses of sheared shale that generally strike northwest and dip steeply northeast. Lenses of bedded chert with generally similar attitudes occur sporadically. Greenstone, possibly metamorphosed from basaltic flows, occurs as occasional lenses, some very thick. The Franciscan sequence, if not isoclinally folded or fault repeated, must be many thousands of feet thick. It is injected by numerous sill-like masses of serpentine that become increasingly numerous northwestward.

In lower Oso and Redrock Canyons the Franciscan is composed of sandstone and shale, and strikes roughly N. 70° W. and dips 20° to 50° N. The total exposed thickness of this section is probably about 2,000 feet. On the west side of lower Oso Canyon a prominent lentil of bedded chert about 50 feet in thickness crops out near the middle of this section and extends westerly about a mile. In Redrock Canyon is another lentil of similar chert higher in the section.

In the Santa Ynez Mountains south of Blue Canyon the Franciscan consists largely of shale and sandstone. The section dips generally southward, but much of it is so intensely sheared that it is not possible to even estimate the thickness of strata exposed. It includes several intrusive masses of greenstone. The entire section is severely squeezed and forced upward as indicated by Page, Marks and Walker (1951, p. 1778) and it is in fault contact with all adjacent rocks.

Condition of deposition. The Franciscan Formation is unfossiliferous but is of marine lithology and was deposited as a series of sands and muds, probably in a broad sea. The arkosic composition of the sandstones indicate the material was derived from a granitic source area. The cherts were deposited locally as siliceous layers, or may have been deposited as fine-grained rhyolitic volcanic ash and later silicified to chert. Lack of organic material in the Franciscan indicates conditions were unfavorable for marine life.

The presence of numerous bodies of basic igneous rocks that are confined largely to the Franciscan indicates volcanism was active during or immediately after deposition of the Franciscan sediments.

Age. As the Franciscan Formation has yielded no fossils within this region its age in the San Rafael and Santa Ynez Mountains is unknown. All that can be said is that it is slightly older than the Espada Formation, in part of Early Cretaceous age. The lowest beds of that formation yielded the Upper Jurassic form, *Buchia piochii.* In the San Francisco Bay region type Franciscan rocks have yielded the ammonite *Douvilleiceras* determined as late Early Cretaceous (Schlocker, Bonilla, and Imlay, 1954). Recent evidence of the age of the Franciscan Formation suggests that it ranges from Late Jurassic to early Late Cretaceous in the Coast Ranges (Irwin, 1957).

Espada Formation

Definition, and type locality. An enormously thick series of dark greenish-brown shale and thin interbedded sandstone of Cretaceous age exposed over much of the northeastern part of the map area has been referred to the "Knoxville group" by Kew (1919, pp. 5–9) and Nelson (1925, pp. 339–343): and as "Undifferentiated Cretaceous shale" by Page, Walker and Marks (1951, pp. 1735–39). The age of this formation is now known to range from that of the type "Knoxville beds" of White (1885, pp. 19–32) possibly latest Jurassic or Early Cretaceous) of northern California to Late Cretaceous, much younger than type Knoxville. This thick shale formation within the map area

is lithologically the same as that described and mapped by the writer (Dibblee, 1950, pp. 22-23) as the Espada Formation (Cretaceous) in the western Santa Ynez Mountains, with the type locality in Cañada Hondo, near Pt. Arguello, 35 miles west of the map area.

Distribution. The Espada Formation crops out extensively on the southwestern slope of Little Pine Mountain, Camuesa Ridge and Camuesa Canyon; thence eastward to Agua Caliente Canyon, and southeastward through the Santa Ynez River Canyon to the ridge north of Blue Canyon. The Espada Formation of this exposure is strongly deformed into a syncline flanked on the north by an anticline, with both structures plunging eastward.

Topographic expression. As the Espada Formation is mostly shale it is not highly resistant to erosion. It erodes to generally low relief with moderately steep slopes. Hard sandstone layers within the shale crop out as strike ridges, of which Camuesa Ridge is the highest and most prominent. The parallel arcuate strike ridges between Mono and Agua Caliente Canyons are formed by sandstone layers cropping out on the eastward plunging Agua Caliente anticline. The Espada Formation is covered by little or no soil mantle, and supports a moderate growth of brush.

Thickness, lithology and stratigraphy. The large exposures of tilted and folded strata of the Espada Formation between Camuesa and Agua Caliente Canyons reveal a complete section of this formation from base to top. Although this formation is in fault contact with the underlying Franciscan in most places, it appears to be in depositional, probably conformable, contact with it southwest of Camuesa Ridge. At the top the Espada formation grades upward into the formation mapped as unnamed shale at Agua Caliente Canyon. The contact of these two formations is designated arbitrarily at the base of a 175 foot-thick sandstone member that forms the ridge west of Agua Caliente Canyon. Based on this horizon as the top of the Espada Formation in this area, the total thickness of this formation would amount to some 16,000 feet. This is the greatest thickness of this formation exposed in or near the Santa Ynez Mountains, and this section is probably the only one completely exposed.

The Espada Formation of this area is a monotonous series of well-bedded argillaceous to sandy shales, and thin interbeds of hard arkosic sandstone. A notable characteristic is that the shales and sandstones alike are of a prevailing dark greenish-gray color and weather to greenish-brown. Another is that parting planes in the shale or between shale and sandstone are generally speckled with flattened black carbonaceous fragments. Most of these are less than 1 millimeter in longest dimension but occasionally some are as large as 10 millimeters.

The shale is argillaceous to finely sandy and thinly bedded. It disintegrates into small subconchoidal fragments rather than platy slabs. Limestone and calcareous sandstone are commonly interspersed at irregular intervals in the shale as nodules, lentils or beds 1 to 14 inches in thickness. These calcareous rocks are dark gray on fresh surfaces but tan on weathered surfaces.

Sandstone occurs at irregular intervals in the shale as lenticular beds less than an inch to about 10 feet in thickness. The sandstones are dark greenish-gray, massive to laminated, hard, fine-grained, and are composed of well-sorted, subangular grains of feldspar, quartz, dark minerals, and mica flakes, in that order of abundance. The color, texture and grain content is similar to the sandstones or graywackes of the underlying Franciscan. Some of the thin sandstones contain numerous unidentifiable shell fragments as well as rock fragments.

The sandstone beds occur either individually within the shale or as groups of sandstone beds separated by interbeds of shale that aggregate 30 to 100 feet in thickness. These sandstone groups are not confined to any part of the sequence, but are most abundant in the middle and upper parts.

Conglomerate is rare in the Espada Formation. All of it is in lentils less than 50 feet in thickness and traceable not more than a mile or two along strike. The most prominent ones occur in the upper part of the sequence two and three miles east of Mono debris dam, and north of the Santa Ynez River above its juncture with Mono Creek. Several very small ones only a few feet or inches thick occur at various intervals in the lower part of the section in the vicinity of Camuesa Canyon.

The conglomerates are composed of well rounded pebbles and some cobbles usually embedded in a dark hard sandy to argillaceous matrix. The pebbles are all composed of very hard rock types, mainly black cherts and felsitic to porphyritic igneous rocks such as andesite, basalt and rhyolite, which endured an extreme amount of abrasion.

There is no defined sequence of beds in the Espada Formation that is consistent throughout this area. Shale makes up about 90 percent of the formation, sandstone about 10 percent, and limestone and conglomerate a small fraction of 1 percent. Most of the sandstone occurs in the upper half of this series.

On the east side of Mono Canyon, the upper part of the Espada Formation contains two small lenses of serpentine breccia of possibly intrusive, or, more probably, detrital origin (mapped as Franciscan by Nelson, 1925).

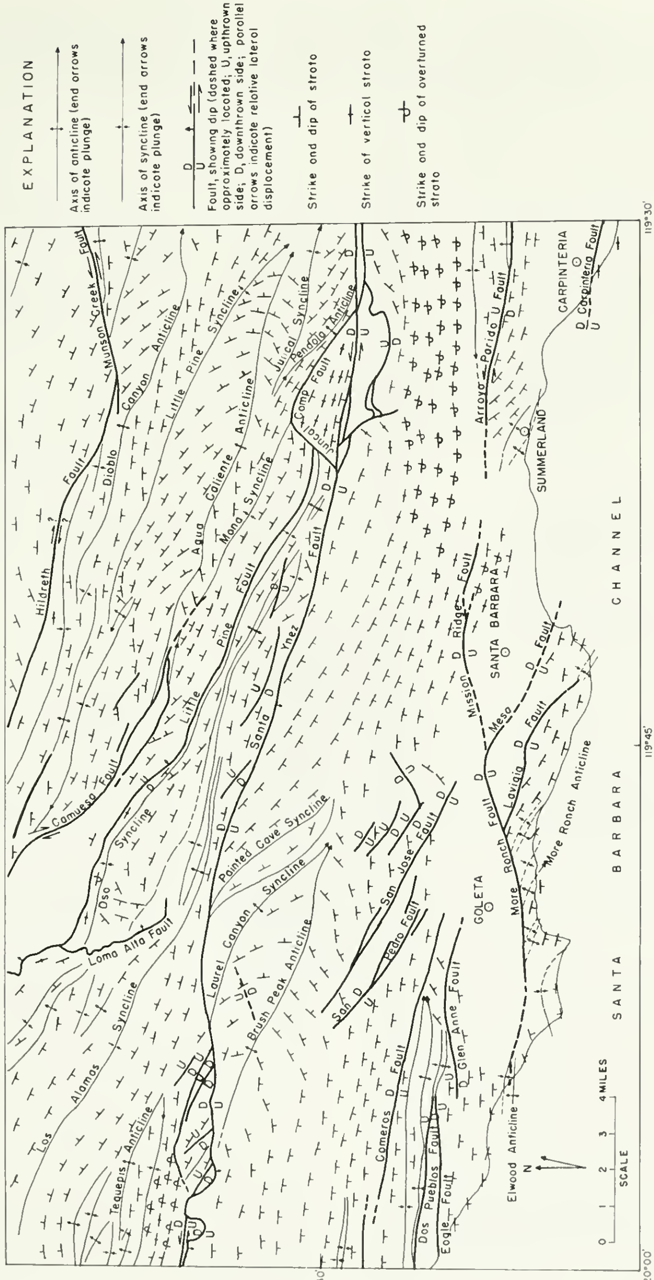


Figure 4. Tectonic map of the central Santa Ynez Mountains, Santa Barbara County, California.

AGE			FORMATION	LITHOLOGY	THICKNESS	DESCRIPTION
QUATERNARY	RECENT		ALLUVIUM (N)		0 – 100'	Gravel, sand, silt
QUATERNARY	PLEISTOCENE	Upper	OLDER ALLUVIUM (N)		0 – 200'	Gravel, sand, silt
QUATERNARY	PLEISTOCENE	Upper	FANGLOMERATE (N)		0 – 100'	Boulder gravel
QUATERNARY	PLEISTOCENE	Lower	SANTA BARBARA		0-2000'	Fine yellow sand
?		?				NOT IN CONTACT
TERTIARY	PLIOCENE	Upper / Lower	PICO		0-2000'	Blue gray siltstone, fine sand; basal conglomerate
TERTIARY	MIOCENE	Upper	SISQUOC			Diatomaceous clay shale
TERTIARY	MIOCENE	Upper / Middle	MONTEREY		1700–2300'	Hard platy siliceous shale; soft fissile to hard platy siliceous shale; thin limestone beds
TERTIARY	MIOCENE	Lower	RINCON		1700'	Gray clay shale
TERTIARY	MIOCENE	Lower	VAQUEROS		300'	Buff sandstone
	?					
TERTIARY	OLIGOCENE		SESPE (N)		2500'	Interbedded gray to buff sandstone and red to green gray siltstone
TERTIARY	OLIGOCENE		GAVIOTA		0-1000'	Buff sandstone
	?					
TERTIARY	EOCENE	Upper	COLDWATER		0-2500'	Buff sandstone, thin beds of gray sandy siltstone
TERTIARY	EOCENE	Upper	SACATE		2500'–3000'	Gray clay shale; minor buff sandstone
TERTIARY	EOCENE	Upper	COZY DELL		1800'–4000'	Gray clay shale; minor buff sandstone
TERTIARY	EOCENE	?	MATILIJA		1000'–2000'	Buff sandstone
TERTIARY	EOCENE	Middle	ANITA		0 – 300'	Clay shale and buff sandstone
CRETACEOUS		Upper	JALAMA		4500' +	Dark gray clay shale; minor thin sandstone beds
						SANTA YNEZ FAULT

Scale: 1000', 2000'

(N) Non-marine formation; all others marine

Figure 5. Stratigraphic column in the Santa Ynez Range south of Santa Ynez fault, west of San Marcos Pass, and coastal area west of Santa Barbara, Santa Barbara County, California.

Condition of deposition. Espada Formation was deposited in warm, shallow, quiet water in a broad subsiding basin. Evidence of shallow water deposition is the abundance of carbonized plant fragments, numerous sandstone interbeds, and presence of some conglomerate. Although shallow, the water was relatively quiet, as suggested by the great thickness of thin-bedded shale and presence of thin limestone layers. The rudistid *Corallichama oscutti* White found in the upper part of the formation is a tropical form, indicating warm water. The enormous thickness of this clastic formation indicates that the sediment accumulated on a rapidly subsiding sea floor and was derived from long continued erosion of an adjacent land area.

Age. Fossils are generally sparse in the Espada Formation, but those present indicate Cretaceous age. They are:

Mollusca
- *Acila demessa* Finley
- *Coralliochama orcutti* White
- *Buchia crassa* (Pavlow) (= "*Aucella*" *crassicollis* Pavlow)
- *Buchia piochii* (Gabb) (= "*Aucella*" *piochii* Gabb)

Ammonoidea
- *Baculites* sp.
- *Puzosia* sp.

Buchia piochii has been reported by Nelson (1925, p. 342) and Page, Marks, and Walker (1950, p. 1739) from the lowest exposed part of the Espada Formation adjacent to the Santa Barbara reservoir. This species is found in formations believed to be of uppermost Jurassic age, such as the Knoxville formation of Hinds (1933) of northern California.

Buchia crassicollis (crassa) has been found in the lower part of the Espada Formation on a fire road 2½ miles northwest of Camuesa Peak. This species is found in formations believed to be of Early Cretaceous age, such as the Paskenta Formation of northern California.

All the other species listed indicated Late Cretaceous age and were found in the upper part of the Espada Formation. Page, Marks, and Walker (1951, p. 1738) report an ammonite Puzosia (?) from Little Caliente Canyon 6,760 feet N. 64° E. of Mono Debris Dam; and the rudistid *Coralliochama orcutti* from a conglomerate bed a mile southeast of the aforementioned locality, and, from the fault block bounded by Blue Canyon and the Santa Ynez River, two species of ammonites, a large baculite, the pelecypod *Acila demessa*, and the rudistid *Coralliochama orcutti.*

Correlation. The correlation of the Espada Formation of this area is uncertain. It is of the same lithology as that mapped in the western Santa Ynez Mountains by the writer (Dibblee, 1950, p. 22-23), of which the upper portion yielded *Buchia crassicollis* in San Lucas and Wons Canyons, Los Olivos quadrangle. This indicates the Espada of these exposures is at least in part correlative, on the basis of lithology and fossil content.

However, the correlative of the upper part of the Espada Formation of the map area where it has yielded fossils indicating Late Cretaceous age is less certain. None of the fossils listed, save for *Acila demessa*, have been found in the Santa Ynez Mountains. This part of the sequence appears to be older than the Jalama Formation mapped in the Santa Ynez Mountains, and is undifferentiable from the beds mapped as Espada. Perhaps this part of the sequence represents a continuously deposited series of strata transitional between the Espada and Jalama Formations that is represented by a gap in the Santa Ynez Mountains.

Unnamed Shale

Distribution and topographic expression. The unnamed shale of Upper Cretaceous age crops out in the San Rafael Mountains near Cachuma Mountain, and also in Agua Caliente Canyon. Because it is mostly shale it is eroded to low relief as is the Espada Formation.

Lithology. The unnamed shale is composed of shale and lesser amounts of interbedded sandstone. The shale beds differ from those of the Espada Formation in being grayer, more micaceous, and generally lack the abundant black carbonaceous flecks in bedding planes. The sandstone beds differ from those of the Espada in being buff to light gray rather than olive gray, are composed mainly of feldspar and quartz, and contain less dark grains. Contacts with the underlying Espada Formation and overlying unnamed sandstone are gradational.

Stratigraphy. Near Cachuma Mountain the unnamed shale ranges from 2,000 to 4,000 feet in thickness. A lens of dark olive-gray conglomerate that thickens northwestward from Cachuma Mountain occurs at the base. It thins out southeastward, but other small lenses appear higher in the sequence in Lazaro Canyon. The cobbles of these conglomerates are well rounded and are composed mostly of quartzite, dacitic porphyries, and granitic rocks. Sandstones become increasingly numerous upward in this sequence as it grades into the overlying unnamed sandstone.

In Agua Caliente Canyon the unnamed shale ranges from 3,000 to 5,000 feet in thickness. In the lower part of the canyon near the debris dam the sequence is about 3,170 feet thick. The base is taken as the gray-

white sandstone from 50 to 175 feet thick exposed on the ridge west of the canyon. This and other sandstones of this sequence are very lenticular and do not persist over any great distance. The upper 1,300 feet contains increasingly numerous thin interbeds of sandstone and this part was included by Page, Marks, and Walker (1951, p. 1737) in their Debris Dam Sandstone. The 200-foot thick lens of brecciated serpentine 1½ miles south of Hildreth Peak is either an intrusive sill or is a sedimentary breccia of serpentine rubble.

Age and correlation. No fossils, other than *Inoceramus* prisms and undiagnostic foraminifers, were found in the unnamed shale. However, its position stratigraphically above the Espada Formation which contains Late Cretaceous fossils near the top and below the unnamed sandstone which also contains Late Cretaceous fossils indicate its age to be also Late Cretaceous, possibly in part correlative with the Jalama Formation of the Santa Ynez Range.

In Agua Caliente Canyon, according to Page, Walker, and Marks (1951, p. 1744), the Pendola Shale yielded a foraminiferal fauna indicating very late Cretaceous age (Senonian or Maestrichtian). In addition it has yielded numerous prismatic fragments of the pelecypod *Inoceramus*. This shale may be correlative with the Mono Shale (of Nelson, 1925) in Mono Canyon, and with the type Jalama in the western Santa Ynez Mountains.

Unnamed Sandstone

Distribution and topographic expression. The unnamed sandstone of Late Cretaceous age is exposed extensively in the San Rafael Mountains eastward from Cachuma Mountain, in the mountains of Hildreth Peak and westward to Indian Creek, and in the mountains mostly east of Agua Caliente Canyon.

This thick sandstone unit has resisted erosion to form the highest part of the San Rafael Mountains, and the rugged mountains of Hildreth Peak and east of Agua Caliente Canyon.

Lithology. This unit is a sequence of sandstone and lesser amounts of interbedded shale. The sandstones are buff to light gray, bedded, hard where unweathered, fine to coarse grained, arkosic, composed mostly of feldspar and quartz, some mica. They are nearly similar to the Eocene sandstones. The shales are similar to those of the underlying unnamed shale and to Eocene shales.

Stratigraphy. In the vicinity of McKinley and San Rafael Mountains the unnamed sandstone may be as much as 9,000 feet thick. It contains very little shale. It is unconformably overlain by the "Temblor" white sandstone to the north, and near Cachuma Mountain.

In the mountains of Hildreth Peak and westward, about 8,000 feet of the unnamed sandstone is exposed. This unit includes the section exposed in Mono Canyon described in detail by Nelson (1925, p. 344-345). Also included in this unit are the Indian Conglomerate and Mono Shale of Nelson (1925, p. 350-352) which he assigned to the Eocene but are now known to be Late Cretaceous. In this section the Indian Conglomerate is 25 feet thick, is composed of quartzite, porphyry, and granite cobbles in a sandstone matrix. It thickens northwestward to 500 feet at Indian Creek. The Mono Shale is 700 feet thick and is composed of thinly interbedded shale and sandstone. It is overlain on the northeast by the Sierra Blanca Limestone and red foraminiferal shale at the base of the Eocene sequence.

In upper Agua Caliente Canyon the unnamed sandstone is about 7,000 feet thick, but it thins southward as it is overlapped by the Eocene sequence. In this area it contains more shale than in areas to the northwest. It includes the upper 1,500 feet of the Debris Dam Sandstone and the 1,000-foot thick Pendola Shale described in detail as local units by Page, Marks, and Walker (1951, p. 1739–1744, fig. 2).

Conditions of deposition. The unnamed sandstone accumulated under a widespread shallow sea as a series of deltaic sands and some muds. The area must have subsided continuously as indicated by the great thickness of sediments. They were derived from a source area of predominantly granitic rocks, which presumably was to the east of northeast.

Age and correlation. In the San Rafael Mountains east of McKinley Mountain, a few *Inoceramus* prisms were found in the unnamed sandstone unite, indicating it to be of Upper Cretaceous age. In Auga Caliente Canyon, according to Page, Marks, and Walker (1951, pp. 1741–42), molluscan and foraminiferal fossils were obtained from a calcareous sandstone bed 30 to 60 feet below the top of their Debris Dam Sandstone. These include the following species:

Cucullea sp.
Spondylus rugosus Packard
Lima aff. *L. beta* Popenoe
Trigonia inezana Packard
Panope cf. *P. californica* Packard
Oligoptycha obliqua (Gabb)
Volutaderma sp.
Perissitys brevirostris (Gabb)
Eutrephoceras sp.
Baculites sp.

Three of these genera were found in the Jalama Formation of the western Santa Ynez Mountains. Defi-

nite correlation, however is uncertain as there are no common species.

Jalama Formation

Type locality. The Jalama Formation consists of several thousand feet of marine sandstone and shale of Upper Cretaceous age in the Santa Ynez Mountains. The type section is in the western part of this range and was described and mapped by the writer (1950, pp. 22–23, map).

Distribution. Within the map area the upper part of the Jalama Formation crops out at two places just south of the Santa Ynez fault on the north flank of the Santa Ynez Range. One is north of Santa Ynez Peak, where the Jalama Formation crops out for a distance of about 6 miles. The other is from a point 1½ miles south of Gibraltar Dam to Romero Pass.

Topographic expression. As the Jalama Formation is composed mostly of shale that crumbles on weathering, it is weakly resistant and is eroded to generally low relief. Sandstone beds within it, however, are relatively more resistant and crop out as prominent ledges. The Jalama Formation generally supports a heavy growth of brush.

Stratigraphy in Santa Ynez Peak area. On the north slope of the Santa Ynez Range in the vicinity of Santa Ynez Peak only the upper 1500 feet of the Jalama Formation is exposed south of the Santa Ynez fault, and it is overlain by Eocene shale and sandstone. In this exposure the Jalama Formation is composed mainly of dark gray micaceous argillaceous to silty shale. The shale is hard and black where fresh, but weathers gray and disintegrates into small ellipsoidal fragments. Dark gray impure limestone occurs locally in the shale as concretions or lentils up to a foot in thickness. Occasional thin layers less than a foot to about 5 feet thick of hard, massive, buff, arkosic sandstone occur in groups at several intervals in the shale.

Stratigraphy in Romero saddle area. On the north slope of the eastern sector of the Santa Ynez Range in the vicinity of Romero Pass about 2,000 feet of the Jalama Formation is exposed south of the Santa Ynez fault. An additional unknown thickness is unexposed. The lowest exposed 1,000 feet of this section consists of sandstone and shale and was referred to the Debris Dam sandstone by Page, Marks and Walker (1951, figs. 2, 3, pp. 1739–41). The upper 1,000 feet, composed of conglomerate, sandstone and shale, was described by them as the Romero Conglomerate.

In this sector the Jalama Formation is a sequence of alternating shale and sandstone, with lentils of conglomerate in the upper portion. Shale makes up about 60 percent of the sequence, sandstone about 40 percent, and conglomerate about 10 percent. Shale predominates in the lower part of the sequence, sandstone and conglomerate in the upper part in the vicinity of Romero Saddle.

The shale is dark gray to nearly black, hard, micaceous, argillaceous to silty. It disintegrates into subplaty to ellipsoidal fragments. Fracture surfaces are commonly coated blue-black with manganese oxides. The sandstone is very hard, light gray, weathering buff, fine to medium grained, arkosic. It is interbedded with the shales usually in thin layers a few inches or feet thick, although some beds are as thick as 30 feet. The sandstone beds are generally closely spaced in groups as thick as 200 feet.

The conglomerates occur as lentils as much as 300 feet in thickness associated with the sandstones. They are composed of rounded cobbles as large as 14 inches in diameter, but mostly from 2 to 8 inches, embedded in a matrix of hard arkosic sandstone as described above. They are composed mainly of gray and tan quartzites, and of lesser amounts of granitic rocks, gray to black porphyries, gray cherty rocks, hard shale or slate, and sandy limestone.

West of Romero saddle, the sequence of the Jalama Formation is as given below.

Jalama Formation exposed in Santa Ynez Range half mile northwest of Romero Saddle.

Conformably overlain by Juncal Formation

	Estimated thickness (feet)
Conglomerate and sandstone	200
Shale, and interbedded sandstone	200
Conglomerate and sandstone	130
Shale, and interbedded sandstone	280
Conglomerate and sandstone	150
Sandstone, and interbedded shale	70
Shale, common thin interbeds of sandstone, decreasing downward	1000
	2030

Santa Ynez fault

The conglomerate at the top of this section is the most persistent. Eastward from Romero saddle it is about 300 feet thick and is traceable to the easternmost extent of the Jalama Formation. Westward from Romero saddle it is traceable for about 3 miles, then grades laterally into sandstone and shale. The other conglomerates do likewise, and the entire sequence becomes generally more shaley westward. In the area northeast of LaCumbre Peak the Jalama Formation is predominantly shale, with a minor proportion of sandstone and no conglomerate.

No fossils were found in the Jalama Formation in the Santa Ynez Mountains east of San Marcos Pass. Correlation of this formation with the Jalama of the western Santa Ynez Mountains is therefore doubtful, but its general similar lithology and similar stratigraphic position conformably below the Juncal For-

mation indicates its correlation is probable. The Romero Conglomerate facies is similar to the 25- to 500-foot Indian Conglomerate in Mono and Indian Canyons as described by Nelson (1925, pp. 350–351) and which he erroneously assigned to the Eocene. This conglomerate and the overlying unit he mapped as the Mono Shale are now known to be of Upper Cretaceous age. Correlation of the Romero Conglomerate with the Indian Conglomerate is suggested by Page, Marks and Walker (1951, p. 1743).

Eocene Rocks

A continuously deposited sequence of marine sandstones and shales of Eocene age totaling about 10,000 feet maximum thickness makes up the major portion of the Santa Ynez Range throughout its length, and the mountains east of Agua Caliente Canyon. All but the lowest part of this thick, conformable sequence was formerly assigned to the Tejon Formation (Kew, 1919; Nelson, 1925; Kerr and Schenck, 1928) on the basis of its fossils, and earlier was described as the Topatopa Formation (Arnold, 1912, p. 22). Kerr and Schenck (1928) subdivided the Tejon Formation into several members. In later years the members have been mapped as formations, so that the previously used formation names Tejon and Topatopa have been dropped.

In the eastern and central areas, the Eocene sequence is divisible into five mappable units, now regarded as formations. These are, in ascending order: Sierra Blanca Limestone, Juncal Formation, Matilija Sandstone, Cozy Dell Shale, and "Coldwater" Sandstone. In the extreme western area, this sequence is divisible into the following units in ascending order: Anita Shale, Matilija Sandstone, Cozy Dell Shale, Sacate Formation, "Coldwater" Sandstone, and Gaviota Sandstone.

Sierra Blanca Limestone

Type locality. A thin basal limestone, first described and mapped as the Sierra Blanca Limestone by Nelson (1925, pp. 352–54) occurs at the base of the Eocene sedimentary sequence in many places in the area north of the Santa Ynez River. It was named after Sierra Blanca Mountain that lies between Indian and Mono Canyons about 7 miles north of their juncture. The limestone crops out prominently along the crest of that mountain, where it attains its maximum thickness of 225 feet. The type locality is at Indian Creek. The Sierra Blanca Limestone has been mapped and described in detail by Keenan (1932), Walker (1950), and Page, Marks and Walker (1951, pp. 1745–49).

Distribution. In the map area, the Sierra Blanca Limestone crops out discontinuously in lower Redrock and Oso Canyons. Near Mono Creek it crops out on both flanks of the Mono Syncline within 1½ miles of Mono Canyon, and on the north side of Blue Canyon. It does not occur at the base of the Eocene sequence in the Agua Caliente area nor in the Santa Ynez Mountains, although its equivalent horizon may be represented by a thin, calcareous, locally fossiliferous sandstone that crops out locally east of Agua Caliente Canyon.

Topographic expression. Because of its hardness and coherence the Sierra Blanca Limestone is resistant to erosion and crops out as a remarkably conspicuous white ledge within dark-colored less resistant shaly strata.

Thickness. In lower Redrock and Oso Canyons the Sierra Blanca Limestone ranges from a wedge edge to 20 feet in thickness. In Blue Canyon the limestone averages about 20 feet and ranges from 10 to 50 feet. In the Mono syncline, it averages about 12 feet and ranges from 5 to 20 feet.

Lithology. The Sierra Blanca Limestone is a massive, hard, firmly cemented, gray-white to tan rock that weathers white. It is an organic limestone, composed essentially of calcareous deposits of algae *(Lithothamnion)*, corals, and orbitoid foraminifers. According to Page, Marks, and Walker (1951, pp. 1746), "at least two genera of corals were recognized and the apparently structureless material that constitutes the great bulk of the formation may be in part of coralline origin". The limestone is commonly sandy, with quartz grains; and pebbles, generally of black cherty rocks, commonly occur in the basal part. In Redrock and Oso Canyons the limestone is very sandy, and contains in the basal part pebbles of colored chert and green sandstone derived from the underlying Franciscan rocks.

Stratigraphic relations. Within the map area the Sierra Blanca Limestone everywhere lies unconformably on older rocks. In Blue Canyon and in the Mono syncline it lies on the Espada Formation with an angular discordance ranging from 5 to 40 degrees. In the latter area it lies on successively older strata from east to west. In Oso and Redrock Canyons, the limestone lies directly on the Franciscan rocks. The limestone is overlain conformably by shale of the Juncal Formation.

Conditions of deposition. In areas north of the Santa Ynez River and west of Agua Caliente Canyon, the Sierra Blanca Limestone formed as a thin encrustment deposited by algae, corals, and other reef-building organisms under clear, warm, shallow waters of a transgressing sea. The limestone existed as a fringing reef, as the Eocene sea transgressed northward onto the eroded surface of older rocks of a land area that

emerged after deposition of the Upper Cretaceous sediments.

To the southeast, at Agua Caliente Canyon, and to the south, in the Santa Ynez Range, no limestone was deposited as the Eocene sea transgressed over the area, probably for several reasons: 1) the sea water may have been too muddy or sandy, or 2) too deep, or 3) this area may have remained submerged from Late Cretaceous into Eocene time.

Age. The age of the Sierra Blanca Limestone was determined to be middle Eocene by Keenan (1932, p. 77), possibly equivalent to the upper Meganos or lower Domengine Formations of the San Joaquin Valley. The foraminifers of the overlying shale of the Juncal indicate that the Juncal is about the same age, if not somewhat older than those formations.

Page, Marks and Walker (1951, p. 1748) list the following fossils from the Sierra Blanca Limestone:

Algae
- *Mesophyllum schencki* Howe
- *Archeolithothamnium* sp.
- *Lithothamnium* sp.

Foraminifera (orbitoids)
- *Pseudophragmina (Proporocyclina) psila* (Woodring)
- *Actinocyclina* sp.

Vermes
- *Tubulostium tejonense* (Arnold)

Brachiopoda
- *Hemithiris* cf. *H. Dibbleei* Hertlein and Grant
- *Eogryphus tolmaniiynezensis* Hertlein and Grant

They point out the difficulties of determining the age relations of California Eocene strata but indicate that the Sierra Blanca possibly falls within the Capay "stage". In terms of present usage, the Capay is regarded as lower Eocene.

Juncal and Anita Formations

Usage of names. The Juncal and Anita Formations are both composed of shale and sandstone of Eocene age that lie on the Sierra Blanca Limestone where present; where the Sierra Blanca is not present, they overlie the Jalama, Espada or Franciscan Formations, and underlie the Matilija Sandstone. The Juncal and Anita Formations are probably time-stratigraphic equivalents, in part if not in whole, but are mapped as different formations in different areas because they have been traced from widely separated type localities.

Type localities. The Anita Shale was named, mapped and described by Kelley (1943, p. 8) for exposures west of Santa Anita Canyon in the western Santa Ynez Range, Point Conception quadrangle, 19 miles beyond the western border of the map area. From that type locality the Anita Shale was traced eastward—being recognized at several areas on the north slope of the Santa Ynez Range (Dibblee, 1950, pl. 1)—to the western border of the map area northwest of Santa Ynez Peak.

The Juncal Formation was named, mapped and described by Page, Marks, and Walker (1951, p. 1749) for exposures north of Juncal Camp and east of Agua Caliente Canyon, in the northeastern part of the map area. The type section is along the axis of the Agua Caliente anticline from about 1 to 2 miles east of Agua Caliente Creek.

Distribution. The Anita Formation crops out on the north slope of the Santa Ynez Range, north of Santa Ynez Peak, and has been traced eastward from its exposure in the adjoining Los Olivos quadrangle (Dibblee, 1951, pl. 1).

All other exposures of Eocene shale and sandstone that lie stratigraphically below the Matilija Sandstone within the map area have been mapped as the Juncal Formation, as described by Page, Marks, and Walker (1951, p. 1749). This formation is exposed extensively in the mountains east of Agua Caliente Canyon.

From the mouth of Agua Caliente Canyon strata mapped as the Juncal Formation extend west in the Mono syncline to Mono Canyon, although the age of these beds is questionable. An isolated exposure of the Juncal Formation occurs farther west in lower Oso and Redrock canyons, where it was mapped as the Meganos Formation by Nelson (1925, pp. 347–48, map).

South of the Santa Ynez Fault the Juncal Formation crops out on the north slope of the Santa Ynez Range, from the slope north of La Cumbre Peak continuously eastward to the eastern border of the map area, and many miles beyond to Sespe Canyon, for a total distance of some 50 miles.

Topographic expression. The shales of the Juncal and Anita Formations disintegrate to small fragments on exposure and therefore weather readily to low or recessive relief. In the Juncal Formation relatively more rapid erosion of the shales leaves the intervening sandstones jutting out as prominent ledges or dip-slopes, or as strike-ridges where they crop out on crests of mountains. Both the Juncal and Anita Formations support a moderately dense growth of brush.

Thickness. The Anita Shale is about 350 feet thick in the Santa Ynez Range northwest of Santa Ynez Peak. Eastward it thins as it grades laterally into sandstone.

The Juncal Formation is about 1500 feet thick in lower Redrock and Oso Canyons. At the type section

in the mountains east of Agua Caliente Canyon, the Juncal Formation is 3360 feet thick, as reported by Page, Marks, and Walker (1951, p. 1750). To the northwest, on the north flank of the Little Pine syncline, it is about 4100 feet in thickness.

In the Santa Ynez Range, east of Romero Saddle for about 3 miles, the Juncal Formation is about 4000 feet in thickness. To the east, it thickens to about 5000 feet or more, and west of Romero Saddle it is about 5400 feet thick.

Lithology. Both the Juncal and Anita Formations are composed of shale and sandstone, with shale predominating. The shales are dark slate gray to dark brownish gray when fresh, lighter gray to grayish buff when weathered. They are nearly always finely micaceous, and argillaceous to silty. Impure dark gray limestone occurs locally in the form of gray concretions or lentils a foot or two thick.

Sandstones of the Juncal Formation are generally hard, well cemented, gray to gray-white and weather buff to buff-white. They are arkosic, fine to medium grained, locally gritty, rarely pebbly. The grains are angular to subrounded, and composed of quartz and feldspar, and some flakes of mica.

Juncal Formation north of Santa Ynez River. In the mountains east of Agua Caliente Canyon the Juncal Formation is divisible into three major members, as described by Page, Marks, and Walker (1951, pp. 1750–52). These consist of an upper shale member (N-3); a middle sandstone and shale member (N-2) and a lower sandstone member (N-1). At the base of the formation of this area is a 1- to 5-foot-thick bed of locally calcareous sandstone that contains abundant *Ostrea idriaensis* and other fossils including calcareous algae and orbitoid foraminifers. This bed lies unconformably on the Pendola Shale and Debris Dam Sandstone units of the Jalama Formation, and is probably the sandy facies of the Sierra Blanca Limestone. This basal bed is prominently exposed in the anticline just northwest of Juncal Camp.

The stratigraphic sequence of the type section of the Juncal Formation 1½ miles southeast of Big Caliente Debris Dam is as given in adjacent table.

From the mouth of Agua Caliente Canyon the Juncal Formation apparently extends westward on both flanks of the Mono syncline to Mono Canyon. The age of these rocks within the Eocene is questionable as determined from foraminifers (see under "Age and correlation"). However, there seems little reason to doubt this section as being part of the Juncal Formation, as the lithology is typical, and it lies conformably on the Sierra Blanca Limestone that forms the basal bed of this formation. East of the mouth of Agua Caliente Canyon the steeply dipping sandstone and shale beds are apparently continuous with those of the Juncal to the east, with no conclusive evidence of faulting.

The Eocene strata of the Mono syncline consist of shale and sandstone similar to those of the Juncal Formation exposed in the mountains east of Agua Caliente Canyon. Shale predominates, especially on the south flank. On the north flank, the Eocene section is composed of the Sierra Blanca Limestone at the base, overlain by about 2200 feet of clayey to sandy shale and several beds from 1 to 120 feet thick of sandstone. On the south flank the Eocene section is about 1400 feet thick, and consists of the Sierra Blanca Limestone at the base overlain by about 225 feet of sandstone and sandy shale, in turn overlain by about 1170 feet of clay shale and several thin beds up to 20 feet thick of sandstone. These Eocene strata are overlain unconformably by Miocene formations.

In lower Oso and Redrock Canyons, the 1500 feet of predominantly shaly strata ("Meganos" of Nelson, 1925, map) that lie above the Sierra Blanca sandy limestone, where present, and below the Matilija (?) Sandstone, are mapped as the Juncal Formation. The limestone forms the base of this section. Above this is about 250 feet of gray clay shale and interbedded fine grained gray locally nodular sandstones. Next above is about 1000 feet of soft gray argillaceous to silty micaceous shale, that locally contains gray calcareous nodules up to 10 inches in diameter that weather gray-

Juncal Formation (type) exposed east of lower Caliente Creek 1½ miles southeast of Big Caliente Debris Dam.

Overlain conformably by Matilija Sandstone

Member		*Estimated thickness (feet)*
N-3	Shale, dark brown gray, silty; some thin beds (½ ft.–25 ft. thick) of hard fine grained sandstone	600
	Sandstone, buff-white, medium grained, in layers ½ ft.–10 ft. thick	300
	Shale, dark gray, silty, and minor beds ½ ft.–40 ft. thick of sandstone, mostly in lower portion	700
N-2	Sandstone, white, massive, medium grained, concretionary, cliff-forming	50
	Shale, as above	100
	Sandstone, as last above	50
	Shale, as above, and minor thin beds (½ ft.–20 ft.) of sandstone	700
	Sandstone, buff gray, medium grained, gritty	60
N-1	Shale, brown-gray, weathering gray-buff, lower 200 feet fissile	875
	Shale, reddish and greenish	2
	Sandstone (Sierra Blanca Limestone equivalent), hard, calcareous, fossiliferous	1-13
		3440

Underlain unconformably by unnamed sandstone.

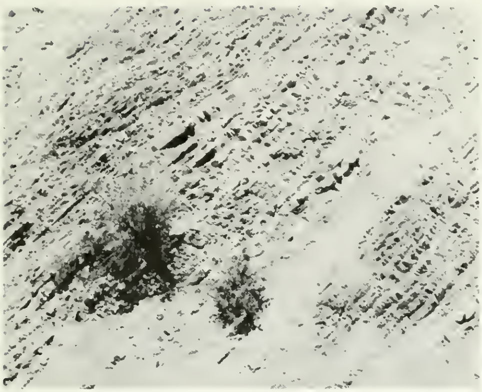


Photo 1. Gray shale of Juncal Formation about 2,500 feet below top. Roadcut near head of Rattlesnake Canyon, Santa Ynez Range.

white. This shale grades upward into about 50 feet of fine grained gray micaceous nodular sandstone that is fossiliferous in Oso Canyon. This in turn is overlain by about 200 feet of gray micaceous siltstone and shale that grades upward into the Matilija (?) Sandstone.

Juncal Formation of Santa Ynez Range. In the Santa Ynez Range eastward from San Marcos Pass the Juncal Formation is similar to that of the type area east of Agua Caliente Canyon, but the entire formation is generally harder and the shale darker. As in the type area, a three-fold division is generally recognizable but there are many lateral changes of facies.

The lower unit, member "S-1" of Page, Marks, and Walker (1951, p. 1751) is about 1200 feet average thickness and is mainly dark shale. In western exposures this unit contains some hard calcareous sandstone in thin layers, most of them less than a foot in thickness. In eastern exposures, southeast of Juncal Camp, the shale contains limestone lenses, most of them less than a foot in thickness and about 5 feet in length. Several contain orbitoid foraminifers and brachiopods, and some are locally conglomeratic, as reported by Page, Marks, and Walker (1951, p. 1751).

The middle unit, member "S-2," named the Camino Cielo Sandstone member by Page, Marks, and Walker (1951, pp. 1751–52), averages about 1900 feet in thickness and consists of sandstone and shale. Shale makes up the greater proportion of this unit but the sandstone strata crop out more prominently and give the false impression that the unit is predominantly sandstone. The lowest sandstone stratum is the thickest and most persistent, and within a mile west of Romero Saddle it is as much as 500 feet in thickness. It is medium grained and locally gritty. West of Romero saddle it contains near the base pebbles of porphyrytic rocks, quartzite and black chert, and subrounded flattish fragments of gray shale, some as large as 2 feet in longest dimension. The other sandstone strata of unit S-2 are thinner, fine to medium grained, and less persistent. All the thicker mappable sandstone strata of unit S-2 grade along strike westward into alternating sandstone and shale, or thin out, within about 6 miles west of Romero saddle.

The upper unit of the Juncal Formation (members "S-3" and "S-4" of Page, Marks, and Walker, 1951, p. 1752) averages about 1900 feet in thickness and is predominantly shale. The shale is dark gray to nearly black, and disintegrates to small spheroidal fragments with blue-black manganese stains on fracture surfaces. In the Romero saddle area and to the east, the shale contains numerous thin 1- to 18-inch-thick interbeds of hard fine grained micaceous sandstone that weather out into slabs. These decrease in abundance to the west.

The contact of this dark shale unit with the overlying light colored Matilija Sandstone is abrupt in some places, gradational through thin interbeds of sandstone in others.

The stratigraphic sequence of the Juncal Formation 3 miles west of Romero saddle is fairly representative of that of the eastern sector of the Santa Ynez Range and is as given below.

Juncal Formation exposed on Santa Ynez Range from 1 to 4 miles west of Romero saddle.

Conformably overlain by Matilija Sandstone

		Estimated thickness (feet)
S-4 and S-3	Shale, gray-black	400
	Shale, gray-black, containing subordinate interbeds from less than an inch to several feet thick of light gray fine-grained sandstone, becoming increasingly frequent downward	1500
S-2	Sandstone, light gray, fine to medium grained, and interbedded gray shale	400
	Sandstone, light gray, micaceous, medium-grained	100
	Shale, dark gray, micaceous, in places containing a few thin beds of fine grained sandstone	1000
	Sandstone, light gray, thick bedded, medium-grained, commonly gritty, basal part locally containing scattered pebbles, and fragments of shale one mile west of Romero saddle; grades laterally westward into interbedded sandstone and shale	500
S-1	Shale, dark gray, containing scattered thin beds from 1 to 3 feet thick of hard light gray sandstone, and occasional lenses as thick as 1 foot of dark gray impure limestone	1100
Total thickness of Juncal Formation		5000

Conformably underlain by conglomerate, sandstone and shale of Jalama Formation

Anita Formation of Santa Ynez Peak area. On the north slope of the Santa Ynez Range in the vicinity of Santa Ynez Peak, south of the Santa Ynez Fault, the Anita Formation has been traced eastward from the area northeast of Refugio Pass, Los Olivos quadrangle, where it is from 350 to 500 feet in thickness and lies below the Matilija Sandstone. At the western border of the map area, the basal 50 feet of the Anita Formation consists of hard arkosic sandstone and shale that rests conformably on dark shale of the Jalama Formation. Above this sandstone bed is about 300 feet of dark gray argillaceous to silty micaceous shale of which the basal 10± feet is locally reddish or greenish. This shale is overlain by the Matilija Sandstone. At the western border of the map area, a prominent bed about 50 feet thick of hard, medium-grained arkosic sandstone appears just above the middle of the shale, and thickens rapidly eastward.

Eastward, the Anita shale grades laterally into sandstone that is similar to and undifferentiable from the overlying Matilija Sandstone, as both the basal and upper sandstone members of this shale thicken and merge with the Matilija north and northeast of Santa Ynez Peak.

Conditions of deposition. The basal fossiliferous sandstone of the Juncal Formation in the area east of Agua Caliente Canyon was deposited, probably contemporaneously with the Sierra Blanca Limestone to the west, upon the eroded surface of Upper Cretaceous strata under a moderately quiet, transgressive sea. The numerous fossils indicate conditions favorable for a marine fauna of the neritic zone. In the Santa Ynez Range, the basal beds of the Juncal and Anita Formations were deposited upon the marine Upper Cretaceous strata with no evidence of an intervening interval of uplift and erosion. The succeeding shales and sandstone of the Juncal and Anita Formations accumulated under conditions probably unfavorable to marine life, judging from the scarcity of fossils, presumably farther from shore, on a sea bottom subject to variations in depth and current. The sediments were probably deposited rapidly as the sea floor subsided. The general eastward thickening of this sequence, combined with the general increase and coarsening of the arkosic sandstone content of the sequence eastward suggests derivation from a land mass of granitic and metamorphic rocks that existed to the east.

Age and correlation. In the mountains east of Agua Caliente Canyon the Juncal Formation contains abundant fossils only in the basal calcareous sandstone bed that is probably equivalent to the Sierra Blanca Limestone. The fossils in this sandstone bed are mostly *Ostrea idriaensis*. The conspicuously curved beak possessed by these specimens (which is not present in the same species from later Eocene formations) probably indicates that these fossils are a variety or subspecies of *Ostrea idriaensis*. The following fossils are reported from this basal sandstone bed by Page, Marks, and Walker (1951, p. 1754):

Algae
- *Archeolithothamnium* sp.

Foraminifera (orbitoidal)
- *Pseudophragmina (Proporocyclina) psila* (Woodring)

Vermes
- *Tubulostium tejonense* (Arnold)

Brachiopoda
- *Eogryphus tolmani* Hertlein and Grant

Mollusca
- *Ostrea idriaensis* Gabb
- *Plicatula* sp.
- *Corbis* sp.
- *Cyclinella* sp.
- *Amaurellina clarki* Stewart
- *Ectinochilus* cf. *E. (Vaderos) elongatus* (Weaver)

In Oso Canyon below the "Narrows", the fossiliferous nodular silty sandstone about 200 feet below the top of the Juncal shale yielded the following species of Mollusca:

- *Schedocardium* cf. *breweri* (Gabb)
- *Ostrea* cf. *idriaensis* Gabb
- *Turritella uvasana* Conrad s.s.
- *Nekewis io* (Gabb)
- *Ficopsis hornii* (Gabb)
- *Amauropsis alveata* (Conrad)

The fossils from both these beds, with the possible exception of the orbitoid foraminifers, are known from formations regarded as middle and/or upper Eocene in other parts of California.

In the Santa Ynez Mountains, about the only megafossils found in either the Anita or Juncal Formations are in limestone lenses in the lower shale member (S-1) of the Juncal Formation southeast of Juncal Camp. These lenses yielded calcareous algae, orbitoid foraminifers, and several species of brachiopods, including *Hemithiris dibbleei*, according to Page, Marks, and Walker (1951, p. 1755). This fauna is generally similar to that of the Sierra Blanca limestone in areas to the north. Elsewhere in the Santa Ynez Range, neither the Juncal nor Anita Formations has yielded any fossils.

Page, Marks, and Walker (1951, pp. 1754–55) list 39 species of foraminifers from the lower shale beds near the base of the Juncal Formation from six localities in the area east of Agua Caliente Canyon; these (to-

gether with the megafossils) they report (p. 1755), "both indicate correlation of the Juncal with formations in California generally termed 'middle Eocene' ". They also report (p. 1755) that, from one locality in the same area, shale beds in the middle of the Juncal Formation contain foraminifers (not listed) of early late Eocene age.

On the south flank of the Mono syncline the Juncal Formation, as herein mapped, has yielded foraminifers, as reported by Page, Marks, and Walker (1951, pp. 1760–61). They list 11 species from a 490-foot shale interval separated by 225 feet of sandstone from the Sierra Blanca Limestone below; and 10 species from a 640-foot shale interval at the top of this Eocene section. These shale intervals are separated by 20 feet of sandstone. Only one of the species of foraminifers listed occurs in both intervals. They report (p. 1761) "significantly, the assemblages mentioned point to a late Eocene age, about the same as that of the 'Coldwater' Sandstone, or, perhaps, even younger". Because of this anomaly they indicate these rocks as "undifferentiated upper Eocene", and suggest (1) the presence of an unconformity beneath the uppermost Eocene strata of the district, or (2) that the age determination is erroneous. The unconformity is unlikely, as the Eocene strata of the Mono syncline are in orderly sequence, and mapping of the Eocene rocks in the Santa Ynez and San Rafael Mountains by the writer has revealed no physical evidence of any unconformity within these rocks. The anomaly is most likely in the age determination of the foraminiferal assemblages, and may result from one of two factors: 1) The foraminiferal assemblages in the Eocene of this region may be controlled more by environmental than by time factors; 2) The ranges of foraminiferal species within the Eocene are as yet not definitely known in the Santa Ynez-San Rafael Mountain region. It has not yet been possible to zone the Eocene strata of this region satisfactorily into recognizable time-stratigraphic units on the basis of foraminiferal assemblages, despite the large number of species present.

It may be concluded, though with some doubt, that the basal and lowest beds of the Juncal and Anita Formations are of probable middle Eocene age, and that the middle and upper beds are probably upper Eocene age. These formations probably correlate with the "Llajas Formation" of Simi Valley; "Liveoak shale" of the type Tejon Formation, and the "Canoas silt" of the north Temblor Range.

Matilija Sandstone

Type locality. The type locality of the Matilija Sandstone is 11 miles beyond the eastern border of the map area at Matilija Springs, Ventura quadrangle,

Photo 2. Matilija Sandstone. Santa Ynez Range two miles east of Santa Ynez Peak.

where it was first described by Kerr and Schenck (1928) as the lower of three members of the Tejon Formation. The term Matilija is now generally used as a formation name. From the type locality the Matilija Sandstone is traceable along the crest of the Santa Ynez Range directly into the map area.

Distribution. From the eastern border of the map area the Matilija Sandstone crops out as a continuous strip for 20 miles, along or near the crest of the Santa Ynez Range nearly to San Marcos Pass; there it dips under younger formations.

West of San Marcos Pass the Matilija Sandstone again crops out, south of the Santa Ynez fault, for about 7 miles along the crest of the Santa Ynez Range. North of the fault, sandstone tentatively assigned to the Matilija crops out for about 2 miles in Hilton and Tequepis Canyons, in a steeply north-dipping section.

North of the Santa Ynez River the Matilija Sandstone crops out in the mountains north of Juncal Camp in a southeast-plunging double synclinal structure. Thirteen miles to the west, in Oso Canyon, the Matilija Sandstone is prominently exposed in a southeast-plunging syncline.

Topographic expression. The Matilija Sandstone is highly resistant to erosion and forms the most rugged, craggy terrain in the district. It forms the highest part of the crest of the Santa Ynez Range, and is everywhere characterized by prominent dip-slopes or precipitous bluffs. It forms little or no soil, but supports a scanty to heavy growth of brush, and some groves of fir and pine on high north-facing slopes.

Thickness. North of Juncal Camp the Matilija Sandstone is 1200 feet thick. In the Santa Ynez Range between Sutton Canyon and LaCumbre Peak it is about 2000 feet thick. From LaCumbre Peak west it thins to about 900 feet as it dips under San Marcos Pass. As it emerges west of that pass, it is only about 400 feet thick; but as it continues westward it thickens rapidly, to nearly 2000 feet at Santa Ynez Peak, then thins again to about 500 feet in the Refugio Pass area, Los Olivos quadrangle.

In Hilton and Tequepis Canyons, north of the Santa Ynez fault, sandstone mapped as Matilija is about 1000 feet thick. In Oso Canyon, it is about 800 feet thick.

Lithology. The Matilija Sandstone is medium to fine grained. It is composed of generally well-sorted subrounded grains of quartz and feldspar, the quartz predominating. Locally there are scattered flakes of muscovite. The prevailing surface color is buff; but unweathered surfaces are gray-white or pale greenish gray-white. In the Santa Ynez Range east of Romero saddle much of the sandstone is mottled pale green. Throughout the Santa Ynez Range and north of Juncal Camp the sandstone is hard and well cemented. However, in Hilton and Tequepis Canyon, north of the Santa Ynez fault, and in Oso Canyon it is semi-friable and less compacted.

The sandstone occurs in massive beds 3 to 20 feet thick, separated by partings or layers of sandy micaceous shale a few inches or feet thick. In some places, notably in the vicinity of Hilton Canyon, both north and south of the Santa Ynez fault, the Matilija Sandstone is conglomeratic, with scattered rounded pebbles and cobbles of quartzite, andesitic porphyries, and granitic rocks.

Stratigraphy. In the area north of Juncal Camp the Matilija is composed of three members. The lower member, about 800 feet thick, consists of sandstone in beds 3 to 20 feet thick, separated by shale partings. It grades downward through interbeds into the underlying shale of the Juncal. The middle member, about 300 feet thick, consists of gray micaceous shale. The upper member, about 100 feet thick, consists of bedded sandstone that locally contains fossiliferous concretions at the top. It is overlain conformably by the Cozy Dell Shale.

Photo 3. Typical exposure of Matilija Sandstone (ma) overlain by Cozy Dell Shale (cd). View west across Rattlesnake Canyon, Santa Ynez Mountains.

In the Santa Ynez Range, between the eastern border of the map area and San Marcos Pass, the Matilija Sandstone is composed almost entirely of sandstone in beds 3 to 20 feet thick separated by shale partings. Near the top are several shale interbeds as much as 30 feet in thickness.

In the Santa Ynez Range in the vicinity of Santa Ynez Peak, the thick sandstone mapped as Matilija is similar in character to the Matilija Sandstone farther east in this range. About the only difference is that neither the base nor top follow definite stratigraphic horizons. North of Santa Ynez Peak the Anita shale grades laterally eastward into sandstone undifferentiable from that mapped as Matilija, so that eastward this sandstone rests directly upon the Jalama shale. South of Santa Ynez Peak, the uppermost 350 feet of the Matilija consists of alternating sandstone and shale, that grades laterally westward into strata that are almost entirely sandstone; and eastward into shale mapped with the overlying Cozy Dell.

North of the Santa Ynez fault in the Hilton-Tequepis Canyon area, the sandsone tentatively assigned to the Matilija is composed of generally massive, friable, fine to coarse buff sandstone and minor interbeds of micaceous siltstone. Near the western border of the map area the basal portion is dark gray sandy siltstone with fossiliferous nodules. This may actually be a thin wedge of the Anita or Juncal Formation resting unconformably on the Espada shale. At this locality the Matilija (?) Sandstone is overlain unconformably by Miocene formations, and from Hilton Canyon eastward it is overlain by the "Coldwater" Sandstone with no apparent intervening Cozy Dell Shale.

At Oso Canyon, sandstone ("Tejon" of Nelson, 1925, map) tentatively assigned to the Matilija forms prominent bluffs, and is composed of two members. The lower member, 455 feet thick, consists of medium grained sandstone in massive beds 5 to 20 feet thick, lying conformably on dark gray siltstone of the Juncal. The upper member, 350 feet thick, consists of light gray thick-bedded very fine grained silty sandstone that contains occasional layers of hard calcareous sandstone and some concretions. This member is overlain conformably by the Cozy Dell (?) Shale, and unconformably by the Sespe conglomerate east of Oso

Canyon. A small patch of Matilija Sandstone east of Loma Alta is overlain unconformably by the "Temblor" sandstone.

In the area northeast of Hildreth Peak the equivalent of the Matilija Sandstone is composed of interbedded sandstone and shale that is not certainly recognizable.

Conditions of deposition. The arkosic composition of the Matilija Sandstone indicates that it was derived from a land area of granitic rocks. The granitic detritus was apparently well sorted by submarine currents and spread out as a more or less uniform blanket of sand over the floor of the Eocene sea as the area continued to sink.

Age and correlation. Fossils are rare in the Matilija Sandstone. In the Santa Ynez Range near the eastern border of the map area several species of gastropoda, including *Ficopsis hornii*, were found in the Matilija Sandstone.

Kerr and Schenck (1928, p. 1090) list the following species of molluscs from the Matilija Sandstone in the Santa Ynez Range 11 miles beyond the eastern border of the map area, near Matilija Hot Springs:

Ostrea
Metacerithium
Nekewis io (Gabb)
Turritella uvasana (Conrad)
Meretrix hornii (Gabb)
Pitaria uvasana (Conrad)
Glycymeris sagittata (Gabb)
Psammobia hornii (Gabb)
Spatangus tapinus (Schenck)

Nearly all of these species occur in the type Tejon Formation, upper Eocene, of Kern County.

North of the Santa Ynez river, northwest of Juncal Camp, Page, Marks, and Walker (1951, p. 1757) list the following species from the upper beds of the Matilija Sandstone:

Vermes
Tubulostium tejonense (Arnold)
Mollusca
Nuculana gabbi (Gabb)
Schedocardia breweri (Gabb)
Macrocallista hornii (Gabb) ?
Macrocallista hornii sp.
Pseudoperissolax blankei (Conrad)
Olequahia hornii (Gabb) ?
Ficopsis hornii (Gabb)

All these molluscan species except *Macrocallista* sp. are found in the Liveoak silt member of the type Tejon Formation of late Eocene age (Marks, 1943, p. 535), southern San Joaquin Valley, and one, *Schedocardia breweri*, occurs in the overlying Metralla sandstone member of that formation. The occurrence of these species in the Matilija Sandstone points strongly to its correlation with the Liveoak silt and possibly the Metralla sandstone members of the Tejon Formation, and to its age as upper Eocene.

West of Hilton Canyon, north of the Santa Ynez fault, fossiliferous nodules of the basal siltstone of the Eocene section yielded *Turritella uvasana* s.s. Conrad and *Galeodea* sp. Eastward in this section, in a canyon half a mile east of Hilton Creek, *Turritella uvasana* s.s. and *Ostrea idriaensis* were found in the Matilija (?) Sandstone about 700 feet below (south of) the Sespe contact. These last two species were found also in the Matilija (?) Sandstone in several cores between 2360 and 2430 feet in the Richfield Oil Corp. San Marcos well No. 2 drilled near the mouth of Tequepis Creek. The *Ostrea idriaensis* from both places is of the same variety as that occurring abundantly in the basal bed of the Juncal Formation east of Agua Caliente Canyon.

On the basis of the above faunas the Matilija Sandstone can be correlated with the type Tejon Formation of Kern County, and is of upper Eocene age.

Correlations within the area. There is some question concerning the correlation of all the exposures of sandstone herein mapped as Matilija. Such has been expressed by Bailey (1952, p. 178). The correlations are based on lithologic similarity and similar stratigraphic position, where fossil control is lacking. Lateral changes in lithology and thickness from place to place, however, make these criteria uncertain, even though the general sequence of stratigraphic units is fairly consistent throughout the Eocene of this district.

There can be little doubt concerning the correlation of the Matilija Sandstone of the area north of Juncal Camp with that of the Santa Ynez Mountains to the south, as the stratigraphic sequence and thicknesses of the various Eocene units is very nearly the same in both areas, except for details.

The correlation of the Matilija (?) Sandstone of Oso Canyon with that of the two areas mentioned above is less certain, as there the Eocene section below is much thinner and contains no thick sandstone members. The correlation of the Matilija (?) Sandstone of the Hilton Canyon area is even less certain as there are no Eocene shale beds above it that can be correlated with the Cozy Dell Shale of the Santa Ynez Mountains. In both places the lithology is the same as that of the Matilija Sandstone, and the fossils of the Hilton Canyon section indicate it is the lower part of the Santa Ynez Mountain Eocene, as *Turritella uvasana* Conrad s.s. has not been found in formations younger than the Cozy Dell Shale in these mountains.

In the Santa Ynez Range west of San Marcos Pass, the correlation of the thick sandstone mapped as Ma-

Photo 4. Cozy Dell Shale (cd) overlain by "Coldwater" Sandstone (cw). View west across Rattlesnake Canyon, Santa Ynez Mountains.

tilija that forms the high ridge of Santa Ynez Peak with the true Matilija Sandstone east of that pass is uncertain. This is because in the western sector the Anita Shale and its sandstone facies below the sandstone mapped as Matilija is very much thinner than its supposed equivalent, the Juncal Formation, in the eastern sector, and the overlying shale mapped as Cozy Dell in the western sector is somewhat thicker than the true Cozy Dell Shale in the eastern sector.

The above relations suggest that the Matilja Sandstone as mapped in the western sector may be equivalent not to the true Matilija of the eastern sector, but to a sandstone member in the underlying Juncal Formation, such as the Camino Cielo Sandstone Member, as suggested by Bailey (1952, p. 178). If so, then the equivalent of the true Matilija Sandstone of the eastern sector would be a 300-foot sandstone member 1000 feet stratigraphically higher than the supposed Matilija Sandstone of the western sector; this 300-foot member strikes across the crest of the range 2 miles northwest of Brush Peak, lenses out 4 miles west of that peak, and is within shale mapped as Cozy Dell.

While the alternative correlation suggeted above is quite possible, it is believed improbable, for 1) the Camino Cielo Sandstone Member grades laterally westward into beds predominantly shale, as previously indicated; 2) the Juncal-Anita sequence thins generally from east to west (from 12,000 feet in Pine Mountain-Mutau flat area to a few hundred feet or nothing in western Santa Ynez Range); 3) sandstones within the Juncal Formation are highly lenticular; and 4) from San Marcos Pass eastward for some 50 miles to Sespe Canyon, Ventura County, the Matilija Sandstone, together with the overlying Cozy Dell Shale, are very consistent mappable units; and the same holds true for the units mapped as Matilija Sandstone and Cozy Dell Shale from San Marcos Pass westward nearly to Point Arguello. For these reasons—though they are not conclusive—it seems likely that the units mapped as Matilija Sandstone and Cozy Dell Shale throughout the Santa Ynez Range are the same stratigraphic units, at least in part.

Cozy Dell Shale

Type locality. The type locality of the Cozy Dell Shale is about 13 miles beyond the eastern border of the map area at Cozy Dell Canyon, Ventura quadrangle, where it was first described by Kerr and Schenck (1928) as the middle of three members of the Tejon Formation. The term Cozy Dell is now generally used as a formational name. At the type locality the Cozy Dell Shale lies above the Matilija Sandstone and beneath the "Coldwater" Sandstone, and is traceable directly into the map area along the south slope of the Santa Ynez Range.

Distribution. In the Santa Ynez Range the Cozy Dell Shale parallels the Matilija Sandstone, cropping out adjacent to it on the south. The shale crops out continuously along the south slope of the range except at San Marcos Pass, where it crosses over to the north slope and dips under folded "Coldwater" Sandstone.

North of the Santa Ynez River the Cozy Dell Shale is largely removed by erosion. The only place where most if not all of it is preserved from erosion is in the syncline northeast of Juncal Dam. Fifteen miles to the west, in the syncline across Oso Canyon, only the basal part of the Cozy Dell (?) Shale is preserved from erosion.

Topographic expression. As the Cozy Dell Shale disintegrates into small fragments it is readily eroded and forms markedly recessive topography in relation to the adjacent sandstone formations. Several thin

sandstone strata within the Cozy Dell Shale crop out as prominent ledges. The Cozy Dell Shale generally supports dense brush.

Thickness. In the Santa Ynez Range eastward from San Marcos Pass, the Cozy Dell Shale ranges in thickness from 1650 to 1900 feet and averages about 1700 feet. A few miles northwest of San Marcos Pass, it is about 4000 feet thick in the Elwood-Tecolote Canyon area; but farther west, in the vicinity of Gato Canyon, it thins to about 1550 feet as the upper portion grades laterally westward into the Sacate Formation. In the syncline north of Juncal Camp, the Cozy Dell Shale is at least 2300 feet thick.

Lithology. The Cozy Dell Shale is dark gray but weathers brownish-gray to olive gray; it is argillaceous to silty, and highly micaceous. It is well stratified and readily disintegrates into small subellipsoidal to subplaty fragments. Calcareous nodules or lentils up to a foot in thickness are locally present. The upper part of the shale becomes silty as it grades upward into the "Coldwater" Sandstone.

Thin interbeds a few inches or feet thick of fine grained, hard sandstone are commonly present in the shale. Occasional beds as much as 100 feet thick, or rarely as much as 400 feet thick, of hard, fine to medium grained buff-weathering sandstone occur locally in the shale, mostly in the middle portion.

Stratigraphy. In the Santa Ynez Range eastward from San Marcos Pass, the Cozy Dell Shale has a fairly consistent sequence. In Mission Canyon the sequence is as given below; it is typical throughout this sector of the Santa Ynez Range.

Cozy Dell Shale exposed in Mission Canyon.

Overlain by "Coldwater" Sandstone

	Estimated thickness (feet)
Shale, dark gray, weathering brownish gray, micaceous, bedded, silty to argillaceous; occasional beds up to 5 feet thick of fine grained buff sandstone	1000
Sandstone, fine to medium grained, light gray, weathering buff; minor interbedded siltstone; traceable for over 3 miles in both directions along strike	100
Shale, as above	400
Shale, as above, and interbedded sandstone like that above	150
	1650

Underlain by Matilija Sandstone

Farther east, in the vicinity of Oil Canyon, the Cozy Dell Shale thickens to about 1900 feet; in its upper part it is locally organic, containing petroliferous and sulfurous material. Organic remains such as carbonaceous fragments, foraminifers (mostly arenaceous) and fish scales are locally common.

In the Santa Ynez Range west of San Marcos Pass, the Cozy Dell Shale is similar in lithology to that eastward from the pass, but is thicker. North and northwest of Brush Peak the shale is about 4000 feet thick. To the southwest, in the Tecolote Tunnel section, a thickness of 6600 feet was measured (Redwine et al., 1952), but part of this great thickness may be the result of repetition by faulting. The upper part of this thick shale section grades laterally westward into shale and interbedded sandstone mapped as the Sacate Formation.

On El Camino Cielo Road along the crest of the range northwest of Brush Peak the Cozy Dell Shale is exposed for a distance of 3 miles, dipping about 15° SE. The section along this road is as follows:

Cozy Dell Shale exposed on crest of Santa Ynez Range northwest of Brush Peak.

Overlain by "Coldwater" Sandstone

	Estimated thickness (feet)
Shale, dark gray, micaceous, argillaceous to silty, (grades westward into Sacate Formation)	600
Shale, as above	400
Sandstone, buff, silty, fine grained; traceable westward to Gato Canyon	70
Shale, as above	300
Sandstone, buff, fine to silty, minor shale, traceable westward as prominent ledge to Capitan Canyon	150
Shale, gray, argillaceous to silty	530
Sandstone, buff, massive, fine grained	100
Shale, as above, minor siltstone	300
Sandstone, white, massive, medium to coarse grained, grading downward into fine grained sandstone, traceable northeastward to San Marcos road, lenses out southwestward in Dos Pueblos Canyon	430
Shale, as above	450
Conglomerate, composed of subrounded pebbles and cobbles of quartzite and partly weathered granitic rocks in matrix of dark gray muddy siltstone, lenses out rapidly in both directions	100
Shale, as above, and minor interbedded fine sandstone	670
	4100

Underlain by Matilija Sandstone

The uppermost 670 feet of this shale section thickens westward (in part by westward lateral gradation of the basal beds of the overlying "Coldwater" Sandstone into this shale) to about 1980 feet in Gato Canyon, and becomes the shale and sandstone sequence mapped as the Sacate Formation.

At Gato Canyon, the shale unit mapped as Cozy Dell, or the lower 3500 feet of the Cozy Dell of the Brush Peak section (exclusive of the uppermost 600 feet), thins to about 2000 feet.

Cozy Dell Shale exposed in Gato Canyon.

Overlain by 180 feet of hard sandstone that forms base of overlying Sacate Formation

	Estimated thickness (feet)
Shale, dark gray, micaceous, argillaceous to silty; 40-foot bed of hard fine grained sandstone at middle	870
Sandstone, hard, fine-medium grained, buff (same as 70-foot sandstone bed in Brush Peak section)	170
Shale, as above; 20 feet of fine grained sandstone 300 feet from top; other sandstone beds up to 10 feet thick in lower third	950
	1990

Underlain by Matilija Sandstone

To the west, in Capitan Canyon (east fork), the Cozy Dell Shale is about 1,550 feet thick. The prominent 170-foot-thick sandstone near the middle of this shale unit extends through this canyon and beyond, nearly to Refugio Pass.

In exposures north of the Santa Ynez fault the Cozy Dell Shale is generally similar to the Cozy Dell exposed south of the fault. In the syncline north of the Juncal Dam the Cozy Dell Shale is about 2,300 feet thick and contains several thin layers of hard sandstone. Farther west, in Oso Canyon, the Matilija Sandstone is overlain by about 180 feet of brownish, locally organic clay shale that is probably the basal part of the Cozy Dell.

In the upturned Eocene section immediately north of the Santa Ynez fault, the Cozy Dell Shale crops out at only one place, namely 1½ miles southwest of Gibraltar Dam, where about 300 feet of the upper part is exposed. In the Tequepis Canyon area the Cozy Dell Shale is apparently missing, even though both the "Coldwater" and Matilija Sandstones are present. However the Cozy Dell Shale was encountered below the "Coldwater" Sandstone in the four test wells drilled just south of the Santa Ynez fault. The wells penetrated these formations north of the fault after passing through it.

Conditions of deposition. The Cozy Dell Shale was deposited as fine micaceous mud, probably during the time the Eocene sea that covered this region attained its maximum transgression and depth. During this time the adjacent land areas were probably eroded down to low relief so that they shed only fine material to the Eocene sea. The presence of some organic and siliceous material in the Cozy Dell Shale, both in this area and in the one to the west (Dibblee, 1950, p. 27) indicates that conditions favorable for microscopic marine life existed at that time, at least locally.

Age and correlation. The Cozy Dell Shale has yielded very few megafossils within the map area. *Amaurellina* sp. was found in the conglomerate bed about 670 feet above the base of the Cozy Dell Shale on the crest of the Santa Ynez Range northwest of Brush Peak. Kerr and Schenck (1928, p. 1090) cite *Amaurellina moragai* Stewart, *Ectinochilus canalifer* (Gabb) and *Ficopsis hornii* (Gabb) from the Cozy Dell strata in Cozy Dell Canyon, 13 miles east of the map area. Bailey (1947, p. 1931) cites *Turritella uvasana* (typical) and var. *Sargenti*, *Pecten calkinsi*, *Ficopsis hornii*, *Pseudoperissolax blakei*, *Macrocallista conradiana*, and *Pitaria tejonensis* from the Cozy Dell Shale farther east, at several localities near Ojai. All these species occur in the type Tejon Formation of Kern County and indicate the Cozy Dell Shale to be of upper Eocene age.

The Cozy Dell Shale contains foraminifers at many places, but little sampling or microscopic work has been done. Page, Marks and Walker (1951, p. 1759) list six species identified from the Cozy Dell near Juncal Dam that indicate late Eocene age. In Tecolote, Capitan and Gaviota Canyons the Cozy Dell Shale has yielded a foraminiferal assemblage generally assigned to upper Eocene or zone A-1 and possibly A-2 zones of Laiming (1940), as indicated by Redwine et al. (1952).

Sacate Formation

Type locality. The type locality of the Sacate Formation is 17 miles beyond the western border of the map area in Sacate Canyon, Pt. Conception Quadrangle, in the western Santa Ynez Mountains. It was first described and mapped by Kelley (1943, pp. 10–12), and later by the writer (Dibblee, 1950, p. 28). It consists of about 1000 feet of interbedded sandstone and shale lying conformably between the Cozy Dell Shale below and the Gaviota Formation above.

Photo 5. Outcrop of Cozy Dell Shale, near top. Roadcut on divide east of Rattlesnake Canyon, Santa Ynez Mountains.

Distribution. The Sacate Formation extends from Capitan Canyon southwest of Santa Ynez Peak eastward along the south flank of the Santa Ynez Range, to Elwood Canyon, where it grades laterally eastward into shale undifferentiable from the Cozy Dell Shale.

Topographic expression. As the Sacate Formation within the map area consists largely of shale and siltstone it readily disintegrates into small fragments and erodes to recessive topography, as does the Cozy Dell Shale. Sandstone beds within it crop out as prominent ledges.

Thickness. At the western border of the map area southwest of Santa Ynez Peak the Sacate Formation is about 2450 feet thick. Eastward it gradually thins to about 800 feet in Elwood Canyon and becomes shale undifferentiable from the Cozy Dell.

Lithology. Within the map area the Sacate Formation is predominantly shale like that of the underlying Cozy Dell. It is dark gray, micaceous, and argillaceous to silty. The upper portion is mostly siltstone. Sandstone occurs as occasional beds, usually only a few inches or feet thick but some are as thick as 200 feet. They are gray-white but weather buff, are fine to medium grained, hard, massive to laminated.

Stratigraphy. The Sacate Formation lies conformably above the Cozy Dell Shale. At the western border of the map area the sequence is given in the adjacent table.

Photo 6. Outcrop of Sacate shale and sandstone. Roadcut one mile west of Brush Peak, Santa Ynez Mountains.

Sacate Formation exposed in Capitan (east fork) Canyon.

Overlain by Gaviota sandstone

	Estimated thickness (feet)
Shale, dark gray, micaceous, massive to bedded, silty, traceable westward to Gaviota canyon; grades laterally eastward through sandy siltstone into "Coldwater" Sandstone	850
Shale, as above; minor thin beds to 3 feet thick of fine buff sandstone; sandstone beds disappear eastward; thickens westward	900
Sandstone, gray-white, weathers buff, fine to medium grained, massive to thick-bedded	200
Shale, as above, and minor thin beds of fine sandstone	300
Sandstone, as above	200
	2450

Underlain by Cozy Dell Shale

In Gato and Dos Pueblos Canyons, the Sacate Formation thins to 1940 feet, because the upper 850-foot shale portion in Capitan Canyon grades laterally eastward into sandstone mapped as "Coldwater". The sequence in these two canyons is as given below.

Sacate Formation exposed in Gato and Dos Pueblos Canyons.

Overlain by "Coldwater" Sandstone (1000 feet thick)

	Estimated thickness (feet)
Shale, dark gray, micaceous, massive to bedded, argillaceous to silty, minor thin interbeds up to 5 feet thick of fine grained sandstone	970
Sandstone, buff white, fine to medium grained, hard; lenses out eastward in Dos Pueblos Canyon	200
Shale, as above, and minor thin beds of fine sandstone	600
Sandstone, as above	170
	1940

Underlain by Cozy Dell Shale

The basal sandstone persists as far east as Elwood Canyon, where it lenses out into shale. Eastward from that Canyon all but the upper part of the Sacate Formation becomes shale that is mapped with the Cozy Dell. The upper part of the Sacate shale grades laterally eastward into the basal sandstones of the "Coldwater" in the vicinity of Brush Peak.

Conditions of deposition. The Sacate Formation was deposited under essentially the same conditions as was the underlying Cozy Dell Shale. However, the highest beds were deposited when the Eocene sea began to regress, when sandy sediments began to accumulate.

Age and correlation. Within the map area the Sacate Formation has yielded no diagnostic megafossils. In the type area in the western Santa Ynez Mountains, the following molluscs were found in the Sacate Formation.

Ostrea idriaensis (Gabb)
Venericardia cf. *Horni* (Gabb)
Turritella sp. A
Amaurellina sp.
Cypraea sp.

Photo 7. Exposures of "Coldwater" Sandstone on south slope of Santa Ynez Range. View northeast at head of Maria Ygnacio Canyon.

This fauna is too meager to correlate the Sacate Formation with any other California Eocene formations, but the *Turritella* sp. A is probably a variety of *Turritella variata* Conrad, and is very closely allied with *Turritella variata* var. *lorenzana* Wagner and Schilling that occurs in beds younger than the type Tejon, Kern County. This suggests an uppermost Eocene age for the Sacate Formation. *Turritella* sp. A. is closely related to a Turritella in the "Coldwater" Sandstone within the map area, and the variety of *Ostrea idriaensis* is exactly the same as the Ostrea characteristic of the "Coldwater" Sandstone—suggesting that the Sacate Formation and "Coldwater" Sandstone are the same age, at least in part. This suggestion is verified by the eastward lateral gradation of the upper part of the Sacate Formation into the lower part of the "Coldwater" Sandstone within the map area.

The lower part of the Sacate Formation is equivalent to the uppermost part of the Cozy Dell Shale in the vicinity of San Marcos Pass, as indicated by its eastward lateral gradation into this shale in Elwood Canyon.

The shale and siltsone of the Sacate Formation, in both the type area (Kelley, 1943, p. 13) and within the map area, have yielded a meager foraminiferal fauna suggesting correlation with Zone A-1 of Laiming (1940), or an uppermost Eocene age.

"Coldwater" Sandstone

Type locality. The type locality of the "Coldwater" Sandstone is about 26 miles east of the map area in Coldwater Canyon, a westerly branch of Sespe Canyon 5½ miles northwest of Fillmore, Ventura County. This sandstone was first mentioned by Watts (1896, 1900) and later described by Kew (1924), and Taliaferro (1924, pp. 789–802) as the top member of the Tejon Formation. Farther west at Matilija Canyon, 11 miles east of the map area, this same sandstone was later described by Kerr and Schenck (1928, p. 1090) as the upper of three members of the Tejon Formation, where it lies conformably above the Cozy Dell Shale and below the Sespe Formation. The name Coldwater was unfortunately twice preoccupied in American literature and hence should not have been applied to a rock unit in this district, but it has become so firmly established there that it has been retained in this report, but in quotation marks. It is now generally used as a formation name.

Distribution. From Matilija Canyon the "Coldwater" Sandstone extends to the map area and westward through it, practically to the western border, along the south flank of the Santa Ynez Range, where it is overturned or dips southward. It underlies practically all the San Marcos Pass area, where it is folded. North of Carpinteria Valley is an isolated exposure half a mile wide of "Coldwater" Sandstone.

All the exposures referred to are south of the Santa Ynez fault. North of this fault the "Coldwater" Sandstone crops out at only two places adjacent to it, namely 1½ miles southwest of Gibraltar Dam, and in Tequepis Canyon.

Topographic expression. The "Coldwater" Sandstone is resistant to weathering and erosion and it forms some of the most rugged, rocky terrain in the Santa Ynez range. It is superbly exposed, especially on the south flank of the range, and forms prominent peaks and ridges on which the sandstones crop out as ledges or dip slopes, and siltstones are eroded down to saddles or strike-canyons. The "Coldwater" Sandstone supports a dense growth of brush.

Thickness. The "Coldwater" Sandstone ranges in thickness from 2500 to 3200 feet, averaging about 2700 feet. Westward from Elwood Canyon it thins gradually to about 1000 feet at Gato Canyon, then disappears short of the western border of the map area as it grades into siltstone of the Sacate Formation.

Lithology. The "Coldwater" consists of about 80 percent arkosic sandstone and about 20 percent siltstone and shale. The sandstone is in beds from 1 to 150 feet thick. It is gray-white, weathering to buff, is fine to coarse grained, predominantly medium grained, and composed of moderately well sorted, sub-rounded grains of quartz and feldspar. Flakes of muscovite and/or biotite occur in some layers. The sandstone is moderately well cemented, massive to laminated. Some of the upper beds are cross-bedded, and all cross-beds seen have a westerly component of dip. The upper beds

contain scattered pebbles of quartzite and granitic rocks. Oyster-shell reefs occur locally, and become very common in the upper part. These reefs are usually hard and calcareous, commonly iron-stained brown.

The siltstone and shale interbedded with the sandstone are greenish gray, weather to a brownish color; they are bedded to massive, sandy to argillaceous, with blocky to spheroidal fracture. Some streaks of red siltstone occur near the top in exposures east from Mission Canyon.

Stratigraphy. In exposures east from Arroyo Burro Canyon, the lower 700 feet of the "Coldwater" is composed predominantly of sandy siltstone and some shale, and occasional beds of silty fine grained nodular sandstone. The thickest bed, about 90 feet thick, is ordinarily at or near the base. This portion of the "Coldwater" is regarded by some geologists as the upper part of the Cozy Dell Shale (e.g. Redwine et al., 1952) but west of Arroyo Burro Canyon it grades westward into sandstone.

Above the lower siltstone member is about 300 feet of massive white sandstone that crops out prominently and persists as far eastward as Ojai Valley. The upper 2,000 feet of the "Coldwater" consists of hard sandstone beds as thick as 75 feet and minor interbeds of greenish-gray, locally carbonaceous siltstone. Oyster shell reefs are very common, especially in the upper 1000 feet. Layers of red siltstone, which are very common throughout the "Coldwater" in the Ojai region, are rare in the map area. A few as thick as 5 feet occur near the top in eastern exposures but disappear entirely westward from Mission Canyon. The "Coldwater"

Photo 8. Outcrop of vertical beds of "Coldwater" Sandstone. Roadcut near head of Sycamore Canyon, Santa Ynez Mountains.

Sandstone grades upward through pink coarse sandstone into red conglomerate and sandstone of the Sespe Formation.

The sequence of the "Coldwater" Sandstone in Mission Canyon, which is typical of this unit throughout the Santa Ynez Range eastward from San Marcos Pass, is as given below.

"Coldwater" Sandstone exposed in Mission Canyon.

Overlain by Sespe red beds

	Estimated thickness (feet)
Sandstone, gray-white, weathering buff, hard bedded to massive, fine to coarse grained, mostly medium grained, occurring in beds as thick as 40 feet separated by partings and some interbeds as thick as 50 feet of greenish brown sandy siltstone locally containing carbonaceous fragments; occasional brown calcareous lentils as thick as 5 feet of oyster-shell reefs, mostly in upper part; rare thin layers as thick as 1 foot of reddish siltstone in upper part	2400
Sandstone, gray-white, weathering buff-white, massive, medium grained arkosic	300
Siltstone, dark gray, weathering greenish brown, locally sandy, with spheroidal fracture; locally nodular; common carbonaceous fragments and some casts of small mollusca	500
Sandstone, light greenish brown, massive, fine grained	100
	3300

Underlain by Cozy Dell Shale

In the San Marcos Pass area, the stratigraphy of the "Coldwater" is about the same as in the area to the east, except that the lower siltstone member loses its identity.

West of San Marcos Pass, the siltstone layers become dark gray, and the oyster reefs become less abundant or disappear. In this area the "Coldwater" Sandstone becomes overlain by similar marine sandstone of the Gaviota Formation rather than red beds of the Sespe Formation, as shown on the map. In Dos Pueblos and Gato Canyons the "Coldwater" Sandstone gradually thins westward to about 1,000 feet, and in Capitan Canyon it finally grades laterally westward into siltstone and shale mapped with the Sacate Formation. The siltstone and shale into which this sandstone grades underlies sandstone of the Gaviota Formation in the Gaviota quadrangle and is traceable to Gaviota Canyon, but is erroneously shown as sandstone on the geologic map of that quadrangle (Dibblee, 1950).

In the Tequepis Canyon area north of the Santa Ynez fault, the "Coldwater" Sandstone is difficult to differentiate from the similar-appearing Matilija Sandstone, owing to the absence of the Cozy Dell Shale in this outcrop section. The presence of the "Coldwater" Sandstone in this section is indicated by the occurrence near the top in the easternmost exposures of a layer of dark red clay and a reef of *Ostrea idriaensis* Gabb, of the irregular, dark shelled variety characteristic of the "Coldwater" Sandstone of the south slope of the

Santa Ynez Range. Also, the four test wells drilled just south of the Santa Ynez fault drilled through roughly 1,000 feet of "Coldwater" Sandstone below that fault, then passed into the Cozy Dell Shale.

Conditions of deposition. The "Coldwater" Sandstone is a deposit of granitic detritus that was washed into the sea by streams that must have drained west from a granitic land area, and was deposited as the sea regressed westward and became shallower. These conditions are indicated by the westward gradation of the "Coldwater" Sandstone into siltstone at its westerly exposure; general coarsening of the "Coldwater" Sandstone from bottom to top; by the occurrence, in the upper part, of many oyster reefs which indicate shallow, brackish-water conditions, and by their disappearance in the westerly exposures; and by the presence, in the eastern exposures only, of red silt and clay that indicate on-shore conditions.

The grains of the "Coldwater" Sandstone were sorted by currents and waves. The coarse upper sands and associated oyster reefs were probably laid down in littoral zones near shore, or even in brackish marine tidal embayments. The red silt was probably deposited on shore, on the margin of a coastal plain that began to be built up as the rate of sedimentation exceeded the rate of regional sinking.

Age and correlation. The oyster reefs of the "Coldwater Sandstone are composed almost entirely of *Ostrea idriaensis* Gabb. They are all of the small, irregular dark-shelled variety, similar to those occurring in the Sacate of the western Santa Ynez Mountains, but unlike those in the Juncal and Matilija(?) Formations north of the Santa Ynez fault. In the uppermost beds west of San Marcos Pass some of these oysters are larger and probably allied to *Ostrea tayloriana* that occurs in the overlying Gaviota Formation.

Turritella are fairly abundant in the "Coldwater" Sandstone, and all those seen by the writer are of a species intermediate between *T. uvasana* and *T. variata*, like the so-called *T. uvasana* figured by Arnold (1907, pl. X). This species is abundant on the old San Marcos Pass road just below the Sespe contact. Bailey (1947, p. 1925) lists from a locality 500 feet north of the turn-off of the Painted Cave road, and 1000 feet or so below the base of the Sespe, *Turritella uvasana* var. *washingtoniana*, along with *Tellina lebecki* and *Spisula bisculptura* (?), all indicating a late Eocene (Tejon) age. Bailey (1947, p. 1925) also reports *Turritella uvasana* cf. var. *Sargenti* and *Marcrocallista conradiana*, both in the type Tejon Formation, from a core at 3125 feet, about 580 feet below the base of the Sespe, in the Petroleum Exploration Company McWilliams well No. 1, just west of Santa Barbara; and also from a core at 2653 feet, 15 feet below the base of the Sespe in Carrey Adams' Wright well No. 1, 4 miles northwest of Santa Barbara.

Arnold (1907, p. 23) reports from a locality on the east side of Mission Canyon, 1000 feet below the base of the Sespe, *Cardium brewerii* and *Meretrix uvasana*, both Tejon species, besides the *Turritella uvasana* (var.) figured (Arnold, 1907, pl. X).

Nearly all the molluscan species referred to above, with the exception of the *Turritella* species intermediate between *T. uvasana* and *T. variata*, are upper Eocene fossils occuring in the type Tejon Formation. The intermediate species of *Turritella* is close to *T.* sp. B. (Kelley, 1943, pl. 1) from the "Coldwater" Sandstone in Matilija Canyon, Ventura County; to *T.* sp. A (Kelley, 1943, pl. 1) from the type Sacate; and to *T. variata* var. *lorenzana* from the San Emigdio Formation (upper Eocene or Oligocene) that lies above the (type) Tejon Formation in Kern County. This suggests the "Coldwater", along with the Sacate Formation, to be probably slightly younger than the upper Eocene type Tejon Formation, but older than the Gaviota Formation.

In the Tecolote tunnel section, interbeds of siltstone in the "Coldwater" Sandstone have yielded a meager foraminiferal fauna that reportedly suggests or indicates Refugian age (Redwine et al., 1952). The siltstone west of Capitan Canyon, into which the "Coldwater" Sandstone grades laterally westward, may likewise contain a Refugian foraminiferal fauna, at least in its upper part. If this is so, it would indicate a probable overlap of the upper Eocene molluscan fauna and the Refugian foraminiferal fauna.

It may be concluded that the age of the "Coldwater" Sandstone is about the same age (or in part slightly younger) as the Sacate Formation, or uppermost Eocene, and possibly in part transitional into the Oligocene Refugian stage. For reasons indicated under "Gaviota Formation," the "Coldwater" Sandstone is believed to be older than the Gaviota rather than its equivalent, as it was considered by Bailey (1947, p. 1925).

Gaviota Formation

Type locality. The type locality of the Gaviota Formation is in Cañada de Santa Anita, Pt. Conception quadrangle, 18 miles beyond the western border of the map area, where it was first described by Effinger (1936, pp. 351–352) and later by the writer (Dibblee, 1950, p. 29), as about 1600 feet of sandstone and siltstone lying conformably between the Sacate Formation below and the Alegria Formation above.

Distribution. The Gaviota Formation crops out as a narrow strip on the lower south slope of the Santa Ynez Range, from Capitan to Bartlett Canyons in the Goleta quadrangle.

Topographic expression. The Gaviota Sandstone within the map area has about the same topographic expression as does the underlying "Coldwater" Sandstone, except that it is somewhat less rugged.

Thickness. In Capitan Canyon at the western border of the map area, the Gaviota sandstone is about 1000 feet thick. It thins gradually eastward and disappears at Glen Anne Canyon as successively higher beds apparently grade laterally eastward into the Sespe Formation.

Lithology and stratigraphy. The lithology of the Gaviota Formation within the Goleta quadrangle is like that of the underlying "Coldwater" Sandstone. The Gaviota is practically all massive to thick-bedded buff-weathering fine to coarse well-sorted arkosic sandstone. It is generally less well cemented than the "Coldwater" Sandstone. Some coarser beds contain scattered rounded pebbles of quartzite and granitic rocks. Several scattered oyster shell reefs occur locally.

The Gaviota sandstone lies conformably on the "Coldwater" Sandstone, and is distinguishable only on the basis of its fossil content. In Capitan Canyon and to the west, the base of the Gaviota consists of about 100 feet of massive sandstone that rests on siltstone of the Sacate Formation. As this basal bed is followed eastward it rests on the "Coldwater" Sandstone and is traceable for 8 miles eastward to Bartlett Canyon, where it becomes involved in faulting. About 400 feet above the base of the Gaviota Formation in Capitan Canyon is another layer about 100 feet thick of massive sandstone similar to the basal bed. This bed, too, is traceable eastward nearly to Bartlett Canyon. In that canyon this bed, or one approximately equivalent to it, grades eastward through buff coarse sandstone into cobble conglomerate with rounded cobbles up to 6 inches diameter of quartzite, andesitic porphyries, and granitic rocks. Eastward from Bartlett Canyon this conglomerate becomes the basal conglomerate of the Sespe Formation.

The upper half of the Gaviota Formation, that is, the part above the sandstone bed just described, consists of friable buff sandstone in the area between Capitan and Dos Pueblos Canyons. Eastward, successively higher beds of this part grade laterally into pink to buff sandstones and red siltstones of the basal part of the Sespe Formation. This accounts for the gradual eastward thinning of the Gaviota Formation.

The easternmost extent of the Gaviota Formation or its equivalent beyond Bartlett Canyon has not been determined because of complex faulting. The lowest beds may extend as far as Pedro Canyon, but if so are within the uppermost part of the "Coldwater" Sandstone.

Conditions of deposition. Within the map area the Gaviota sandstone was deposited under the same conditions as was the "Coldwater" Sandstone; that is, under a shallow sea regressing westward as it became filled with sandy sediments. The Gaviota sandstone is the off-shore facies of the lower part of the Sespe Formation farther east, indicating the Gaviota sandstone to have accumulated on the littoral zone just off-shore from a broad coastal plain on which the lower beds of the Sespe Formation were deposited by westward-flowing streams.

Age and correlation. Although the Gaviota sandstone is lithologically the same as the "Coldwater" Sandstone, and was deposited under the same conditions, its molluscan fauna differs greatly in species. The oyster-shell reefs of the Gaviota are composed of *Ostrea tayloriana* rather than the *Ostrea idriaensis* that characterizes the "Coldwater". The Turritella in the Gaviota are all *T. variata* Conrad s.s. These have been found as far east as Elwood Canyon. Just beyond the western border of the map area, in Refugio Canyon, the Gaviota sandstone has yielded, in addition to the two species mentioned above, *Tivila inezana*, *Crassatella collina*, and *Pecten (Chlamys) yneziamus*, all typical Gaviota species which do not occur in the underlying "Coldwater" or Sacate Formations. They indicate a lower Oligocene or Refugian age for the Gaviota Formation. A similar age is indicated by the foraminiferal faunas found in the siltstone facies of this formation west of the map area, according to Schenck and Kleinpell (1936, p. 215–225).

Bailey (1947, pp. 1925–26) suggests that the molluscan fauna of the Gaviota Formation is a facies fauna of the more typical upper Eocene molluscan fauna of the "Coldwater" Sandstone, and is therefore of the same age. This is based on his mapping of the "Coldwater" and Gaviota sandstones as one single stratigraphic unit. However, detailed mapping of individual beds within this sandstone unit, with the aid of aerial photographs shows that the Gaviota sandstone, as mapped west of Capitan Canyon, can be separated from the "Coldwater" Sandstone as mapped to the east. Although the contact mapped between these two units within the Goleta quadrangle marks no lithologic change, it does to the west, between siltstone below and sandstone above; and within the Goleta quadrangle it is the approximate contact between beds that contain the Eocene molluscan fauna below and the Refugian molluscan fauna above. Eastward from Elwood Canyon this contact eventually goes into the base of the Sespe Formation and apparently coincides with it in the San Marcos Pass area and eastward.

The mapping of the Gaviota Formation within the Goleta quadrangle verifies two concepts long held by

California stratigraphers: 1) that the Gaviota Formation is largely a marine facies of the lower part of the Sespe Formation farther east, and 2) is, for the most part at least, younger than the "Coldwater" Sandstone.

Sespe Formation

Type locality. The type section of the Sespe Formation is about 27 miles east of the map area, near the mouth of Sespe Canyon about 4 miles north of Fillmore, Ventura County; the formation was named by Watts (1897) and redefined by Kew (1924).

Distribution. The entire length of the Sespe Formation exposed within the map area extends from east to west along the southern foothills of the Santa Ynez Range. Isolated exposures occur along the north edge of Carpinteria Valley. Other small exposures of Sespe red beds occur at the base of Packard's Hill at the south side of the city of Santa Barbara, and also three miles northwest near Laguna Blanca. On the Santa Ynez Range northeast of San Marcos Pass the Sespe Formation is infolded in a northwest-trending syncline in which it has been preserved, as a remnant, from removal by erosion.

On the north side of the Santa Ynez Range, just north of the Santa Ynez fault, the Sespe crops out as several discontinuous exposures at and near Hilton and Tequepis Canyons; and again opposite the mouth of Oso Canyon and southeastward as far as Blue Canyon. North of the Santa Ynez River the Sespe Formation is missing, except for one outcrop on the east side of Oso Canyon.

Topographic expression. The Sespe Formation erodes to recessive topography and low relief as compared to the more rugged topography formed by the underlying "Coldwater" and Gaviota sandstones. The Sespe generally supports a dense growth of brush, although in places where the Sespe contains a large percentage of clay it weathers to a loamy soil that supports grasses rather than brush.

Thickness. On the south side of the Santa Ynez Range, the Sespe Formation has a fairly uniform thickness averaging about 3000 feet, but with a gradual thinning from east to west. The thickness of the Sespe Formation in the following completely exposed sections is as follows: Northeast of Summerland, 4500 feet; north of Santa Barbara, 3450 feet; south of San Marcos Pass, 2700 feet; Tecolote Canyon, 2500 feet; Capitan Canyon, 2200 feet. In Elwood oilfield the Sespe Formation is 2800 feet thick.

North of the Santa Ynez fault, the Sespe Formation attains its maximum thickness of about 2000 feet in exposures southwest of Gibraltar Dam. At Tequepis and Hilton Canyons, it is about 1000 feet thick; it is overlapped west of the latter canyon by Miocene formations.

Photo 9. Exposures of Sespe Formation (sp), overlying "Coldwater" Sandstone on south slope of Santa Ynez Range. View west from divide on east side of San Jose Canyon.

Lithology. The Sespe Formation is a series of interbedded argillaceous to silty shales, fine to coarse grained sandstones and some conglomerates, with all gradations between each of these types. The formation is generally coarser in the lower part, in which coarse sandstones and conglomerates are abundant, and finer in the upper part, which is composed mainly of shales and fine sandstones. The Sespe is predominantly red or maroon in color, contrasting sharply with the underlying "Coldwater" and Gaviota sandstones, which are light buff in color. The red color is imparted to all rock types of the Sespe Formation by red oxides of iron that impregnate the shales and coat the grains of most of the sandstones.

The shales of the Sespe are compact but not hard, and disintegrate into small spheroidal fragments. They are commonly silty, sometimes sandy or gritty. Generally they are maroon red, but some layers are grayish green or mottled with this color. Others contain layers of small white calcareous nodules.

The sandstone of the Sespe is well sorted and composed mainly of quartz and feldspar. Small fresh flakes of biotite are common in some layers and form prominent laminae. The sandstone beds range in color from maroon-red, pink-gray, brown to buff. They are generally well bedded, the beds ranging from less than an inch to 50 feet in thickness, and averaging about 5 feet in thickness. The Sespe sandstone beds are moderately indurated but semi-friable. The coarser are commonly cross-bedded. All cross-beds seen have a westerly component of dip.

Photo 10. Overturned red conglomerate and sandstone beds of basal part of Sespe Formation. Roadcut on divide west of Sycamore Canyon, Santa Ynez Mountains.

The conglomerates of the Sespe are generally maroon, well bedded, commonly cross-bedded, and composed of smooth, subrounded to rounded pebbles and cobbles embedded in a coarse ill-sorted sandstone matrix. The clasts are composed of many rock types, but mostly very hard types such as quartzites, andesitic porphyries, and Franciscan red and green cherts or jaspers.

Stratigraphy. On the south side of the Santa Ynez Range eastward from San Marcos Pass, the basal part of the Sespe is composed of roughly about 150 feet of maroon to pink sandy conglomerate and coarse pebbly arkosic sandstone. These basal beds are well exposed on the San Marcos Pass highway where they are predominantly red conglomerate; but to the east they are mainly pink sandstone and subordinate conglomerate. They rest accordantly on the "Coldwater" Sandstone; in places the transition is marked by several tens of feet of pink sandstone and clay. Eastward from Rattlesnake Canyon the lowest conglomerate beds contain water-worn shells of *Ostrea idriaensis* apparently derived from the underlying "Coldwater" Sandstone. These conglomerate and sandstone beds grade upward into a series of laminated coarse pebbly to fine-grained red sandstones interbedded with maroon and some green silty shale, and together make up the lower two thirds of the Sespe. The upper third of the Sespe is composed of maroon and some green silty shale and interbedded fine-grained laminated reddish to pinkish-gray sandstone, and some buff-colored sandstone beds that become increasingly abundant westward from Santa Barbara.

In the San Marcos Pass area the stratigraphy of the Sespe is about the same as it is to the east, except that in the upper third most of the sandstone is buff colored, as seen on both the old and new San Marcos Pass highways.

Westward from San Marcos Pass, the basal conglomerate and sandstone become coarse massive pink to light gray sandstone with scattered cobbles. West of Glen Anne Canyon this apparently grades laterally into buff coarse sandstone of the Gaviota Formation. From Tecolote Canyon westward the Sespe contains no basal conglomerates, although the beds of the lower 400-foot portion become quite coarse, pink to light gray, and in places contain scattered pebbles. These coarse sandy beds in part grade laterally westward into marine sandstone of the Gaviota Formation west of Tecolote Canyon, and into those of the Alegria Formation west of Refugio Canyon (Dibblee, 1950, p. 30, map). The Sespe Formation above these lower sandy beds in the area westward from Tecolote Canyon consists of predominantly brownish-gray to buff-colored sandstone interbedded in maroon-red shale and some variegated red and green clay beds.

Photo 11. Basal red conglomerate of Sespe Formation. San Marcos road in Maria Ygnacio Canyon.

Photo 12. Sandstones and red clays of upper part of Sespe Formation. San Marcos road on east side of Maria Ygnacio Canyon.

The Sespe Formation exposed in the syncline just northeast of San Marcos Pass is much the same as in the area south of the pass. The basal conglomerate is about 50 feet thick, dark maroon in color, and is composed mostly of Franciscan pebbles. It grades upward into red sandstone, which in turn grades upward into reddish siltstone interbedded with buff sandstone. In this area the Sespe rests unconformably on the "Coldwater" Sandstone, as northward it gradually overlaps beds of the "Coldwater"; near the Santa Ynez fault it rests on the lower part of this formation.

North of the Santa Ynez fault and east of Paradise Camp the Sespe consists of about 100 feet of basal maroon conglomerate of Franciscan detritus. This conglomerate grades upward into red sandstone and interbedded maroon shale. The Sespe of this area rests disconformably on the basal part of the "Coldwater" Sandstone.

In the Tequepis-Hilton Canyon area, north of the Santa Ynez fault, the Sespe consists of from 5 to 150 feet of gray basal conglomerate, composed of pebbles and cobbles almost entirely of Franciscan sandstone and chert, lying disconformably on the "Coldwater" Sandstone and Matilija (?) Sandstone. This conglomerate grades rapidly upward into the balance of the Sespe, which here consists of brown to gray, laminated, medium- to fine-grained sandstone interbedded with greenish-gray to maroon silty shale.

In Oso Canyon, the Sespe consists of only 150 feet of red conglomerate composed of pebbles of Franciscan sandstone, chert, jasper, and greenstone. On the east side of Loma Alta a similar conglomerate as much as 100 feet in thickness appears; but it is greenish-brown rather than red. At both places the conglomerate rests unconformably on Eocene strata and is overlain without discordance by the "Temblor" Sandstone. It is possible that this "Sespe" conglomerate may be a nonmarine facies of the Vaqueros Sandstone.

Conditions of deposition. The Sespe Formation is the only Tertiary formation of nonmarine origin within the map area, as indicated by its prevailing red color and lack of any marine fossils or marine-type sediments. It accumulated on a nearly level plain that came into existence in Oligocene (Refugian) time, after the Eocene sea finally became filled with sediments. This plain apparently covered the area southward from the present Santa Ynez River, and received a total of from 2200 to 4500 feet of stream-laid sediments of the Sespe Formation. This large thickness indicates continued regional sinking of the area, but at a rate slower than the accumulation of sediments so that it remained above sea level. This plain or valley fronted a retreating sea that flooded the area to the west and extended as far eastward as Glen Anne Canyon during early Sespe time; but then it retreated westward to and beyond the present Gaviota Canyon, as indicated by the lateral gradation of the Sespe red beds westward into marine littoral sand of the Gaviota and Alegria Formations.

During Sespe time the area north from the present Santa Ynez River and west from Mono Canyon apparently became elevated to a mountainous highland (San Rafael uplift of Reed, 1936, p. 13, fig. 6), on which the Franciscan rocks were exposed to erosion. This is indicated by the absence of the Sespe from this area (except in isolated places such as at Oso Canyon), and by the abundant Franciscan detritus in conglomerate of the Sespe throughout the area to the south. This highland was formed during a widespread orogeny, as described in Bailey (1947, pp. 1921–23). This disturbance affected the area southward as far as the crest of the present Santa Ynez Range, causing erosion of the Eocene sediments, as indicated by the disconformity between these and the Sespe Formation in the vicinity of the present Santa Ynez fault. This orogeny is probably the local effect of the Ynezian orogeny that affected the area to the west just prior to Vaqueros time (Dibblee, 1950, p. 62). However, within the map area it started at the beginning of Sespe time, with elevation of the area north of the present Santa Ynez River to a highland that probably remained elevated throughout Oligocene and early Miocene times.

The abundant Franciscan detritus in the conglomerate of the lower part of the Sespe Formation throughout the map area must have been derived from the highland area to the north, and was deposited as alluvial fans by streams that flowed southward from that highland. However, the arkosic composition and abundant biotite flakes of the Sespe sandstone indicate

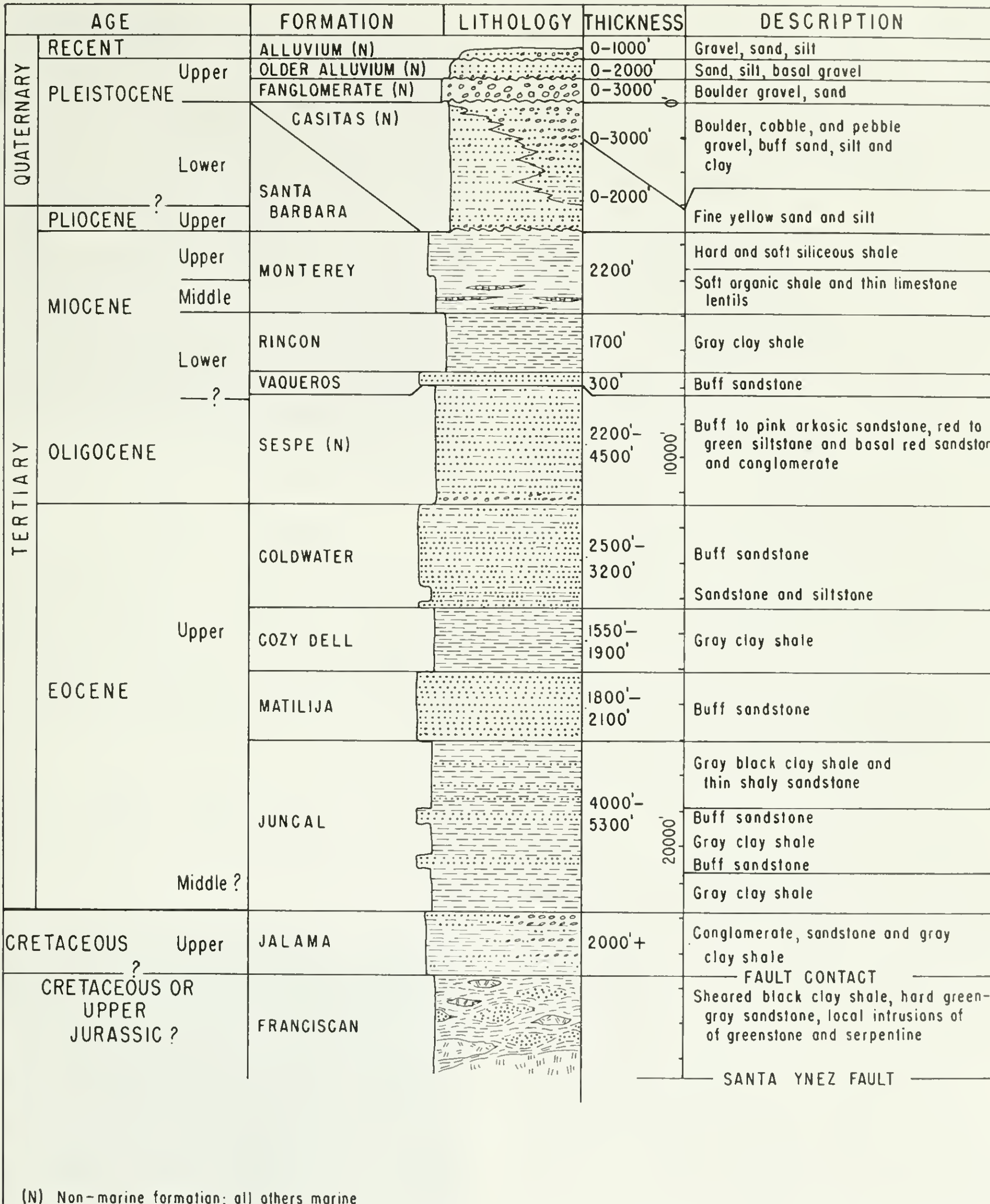


Figure 6. Stratigraphic column of Santa Ynez Range south of Santa Ynez fault, east of San Marcos Pass, and coastal area east of Santa Barbara, Santa Barbara County, California.

most of this formation was derived from an elevated area of granitic rocks. This must have existed east of the plain upon which the terrestrial sediments accumulated; these were probably deposited by streams that drained westward from it. This condition is indicated by the gradual thinning of the Sespe Formation from east to west through the map area, and by its eventual westward lateral gradation into marine arkosic sandstone.

The large amount of iron oxide in the Sespe Formation that imparts the prevailing red color was derived from the iron-bearing minerals of the source rocks. The red iron oxides were apparently produced under climatic conditions of generally high temperature and alternating wet and dry seasons, which would have permitted oxidation of the iron-bearing minerals. On the other hand the presence of fresh feldspar grains and biotite flakes in the Sespe sandstone indicate that the granitic source rocks were not severely weathered, although erosion of these source rocks and deposition of the detritus may have been so rapid that severe weathering did not have time to take effect.

Age. The Sespe Formation has yielded no fossils within the map area other than water-worn shells of *Ostrea idriaensis* near the base. However, its age can be determined by its stratigraphic position and by the age of the marine formations into which it grades laterally to the west.

Its stratigraphic position indicates the Sespe to be younger than the "Coldwater" Sandstone, uppermost Eocene, upon which it rests; and older than the Vaqueros Sandstone, lower Miocene (Zemorrian), which rests upon it. This indicates that the Sespe is probably Oligocene (Refugian) in age.

The Gaviota Formation, into which the lower part of the Sespe grades, contains Oligocene (Refugian) molluscan and foraminiferal faunas. The Alegria Formation, into which part of the Sespe grades, has yielded *Turritella variata, Ostrea tayloriana, Tievla inezana, Macrocallista* cf. *Pittsburgensis, Pecten (Chlamys) yneziana* and *Acila schumardi.* This fauna indicates Oligocene (Refugian) age, as does the Gaviota fauna.

It is possible that the uppermost part of the Sespe, which does not grade laterally into marine beds but is overlapped west of the map area by the Vaqueros Sandstone, according to Bailey (1947, p. 1916) may be of lower Miocene Zemorrian age.

From the foregoing evidence the Sespe Formation within the map area is designated as Oligocene (Refugian) in age; the upper part may possibly extend into the lower Miocene (Zemorrian).

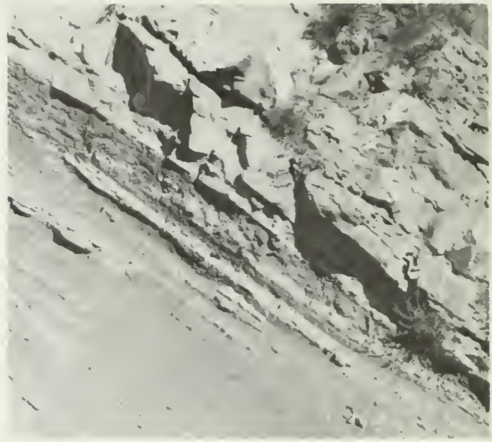


Photo 13. Buff sandstones and red clays of upper part of Sespe Formation. Old San Marcos road east of San Jose Canyon.

Vaqueros Sandstone

Type locality. Hamlin (1904) first named and described the Vaqueros Sandstone at the type locality—exposures of lower Miocene marine sandstone in Vaquero Canyon, in the Santa Lucia Mountains, Monterey County, about 155 airline miles northwest of Santa Barbara. Within the map area a similar marine sandstone of lower Miocene age that overlies the Sespe Formation is generally referred to as the Vaqueros Sandstone.

Distribution. The Vaqueros Sandstone is exposed as discontinuous outcrops along the southern foothills of the Santa Ynez Range from the hills north of Summerland to and beyond the western border of the map area. Two small outcrops of this sandstone are in the hills east of Laguna Blanca near Santa Barbara. In the

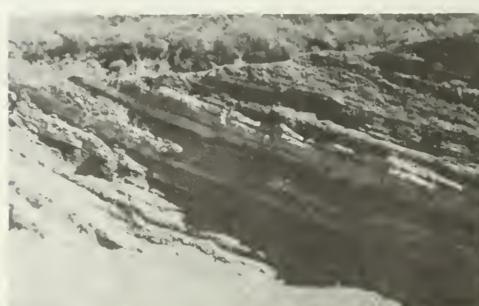


Photo 14. Red clay shale of upper part of Sespe Formation. San Marcos road on east side of Maria Ygnacio Canyon.

north side of the Santa Ynez Range are two outcrop areas of Vaqueros Sandstone, just north of the Santa Ynez fault. The western area extends from Hilton Canyon 3 miles eastward. The eastern and larger area extends from Lewis Canyon eastward to the area south of Gibraltar Dam. North of the Santa Ynez River the Vaqueros Sandstone is absent.

Topographic expression. The Vaqueros Sandstone is more resistant to weathering than either of the adjacent formations and in most places crops out prominently in an area of otherwise low relief. In some canyons, such as Elwood and Glen Anne, it is cut through by narrow gorges. The sandstone supports a heavy growth of brush.

Thickness. On the south side of the Santa Ynez Range the Vaqueros Sandstone is about 300 feet thick between Summerland and the area south of San Marcos Pass, and thickens westward to about 400 feet at Las Yeguas Canyon. On the north side of the range, in the Hilton-Tequepis Canyon area, the Vaqueros is about 150 feet thick, and pinches out west of Hilton Canyon. In the area east from Lewis Canyon it is as much as 600 feet thick.

Lithology. The Vaqueros Sandstone is fine to coarse, generally medium grained. It is composed of well sorted grains of quartz and a subordinate amount of feldspar, and scattered dark grains. Biotite flakes are uncommon or absent. The sandstone is light gray to greenish-gray where fresh but weathers to buff. It ranges from massive or thick-bedded, to locally cross-bedded. Some layers commonly contain fossil fragments or pebbles; others are hard and calcareous.

The fine-grained sandstone of the Vaqueros commonly grades into massive to poorly bedded siltstone. The siltstone is greenish-gray, weathering to light brown. It is commonly nodular, with concretions up to a foot in diameter.

Photo 15. Nodular clay shale of basal part of Vaqueros Formation. San Marcos road one mile east of Rancho San Fernando Rey, north side of Santa Ynez Mountains.

Stratigraphy. The Vaqueros Sandstone wherever present within the map area rests conformably on generally fine grained red beds of the Sespe, and is overlain conformably by clay shale of the Rincon. Both contacts are abrupt in most places, especially on the south side of the Santa Ynez Range, in other places they are somewhat gradational, through several tens of feet of siltstone and fine sandstone—especially in areas north of the Santa Ynez fault.

On the south side of the Santa Ynez Range the Vaqueros is composed almost entirely of thick-bedded to massive, medium-grained sandstone. Scattered pebbles of quartzite, andesitic porphyries, and black chert occur locally near the base. Calcareous beds composed of numerous shell fragments occur locally in the sandstone, mostly in the area between Elwood and San Jose Canyons. In the Elwood Canyon area some of the sandstone is coarse grained and cross-bedded. In the Summerland area most of it is finer grained than in areas to the west.

On the north side of the Santa Ynez Range, the Hilton-Tequepis Canyon area, the Vaqueros is composed of poorly bedded, greenish-gray to buff, fine grained sandstone that locally contains concretions as large as a foot in diameter, but grades upward into sandy siltstone at the top. A few calcareous beds about a foot thick, containing *Turritella ynezana*, are present locally in the upper siltstone zone. In places, the lower part of the Vaqueros of this area is composed of nodular gray siltstone as much as 100 feet in thickness. This is especially well exposed on the highway cut a mile west of Hot Spring Canyon, where it overlies Sespe red and green clays.

In the area eastward from Lewis Canyon, on the north side of the Santa Ynez Range, the Vaqueros consists of sandstone and some siltstone. The Vaqueros of this area is best exposed in a steep-dipping section on the east bank of the Santa Ynez River 2 miles west of Gibraltar Dam, and along strike for a mile in both directions. The lowest 50 feet of this section consists of fine grained silty sandstone, overlain by about 250 feet of thick-bedded grayish buff fine to medium grained to gritty sandstone that forms bold outcrops. This sandstone contains some concretions up to $1\frac{1}{2}$ feet in diameter, and near the top contains several hard calcareous lentils 1 to 2 feet thick that bear *Turritella ynezana* and other shell fragments. Next above is about 120 feet of massive to bedded greenish gray sandy siltstone that contains layers of concretions. Above this siltstone and forming the top of the Vaqueros of this section is from 70 to 150 feet of bedded fine to medium grained sandstone that thickens eastward, and probably thins westward. This sandstone is overlain by siltstone and shale of the Rincon Formation.

Conditions of deposition. The molluscan fossils in the Vaqueros Sandstone, such as the large species of *Ostrea*, *Pecten*, and *Turritella*, are forms similar to those now living in shallow tropical seas. They indicate the Vaqueros Sandstone to have been deposited in a warm shallow sea as it transgressed over the broad level plain that remained emergent during Sespe time. The area north of the present Santa Ynez River, or the San Rafael uplift, that underwent erosion during Sespe time, probably remained emergent during lower Miocene time also, as indicated by the absence of the Vaqueros and Rincon Formations from that area.

Age and correlation. On the south side of the Santa Ynez Range the Vaqueros Formation contains very few well preserved molluscan fossils, although shell fragments are locally numerous. *Pecten (Lyropecten) magnolia* is about the only identifiable species. Most of the shell fragments are of barnacles, *Ostrea*, and other pelecypods.

On the north side of the Santa Ynez Range, the Vaqueros of both the Hilton-Tequepis Canyon area and the area west and south of Gibraltar Dam have yielded the following species of Mollusca:

Ostrea cf. *eldridgei*
Pecten (Lyropecten) magnolia
Pecten (Chamys) sespeensis
Turritella ynezana
Turritella ynezana var. *alticorona*

All these species indicate an early Miocene (Zemorrian) age for the Vaqueros Sandstone of this area. The Vaqueros is probably of early Zemorrian age, as the lower part of the Rincon Shale above it is of late Zemorrian age.

Rincon Shale

Type locality. The type locality of the Rincon Shale is in Los Sauces Canyon on the east side of Rincon Mountain, Ventura quadrangle, about 10 miles east of Carpinteria, where it was first described by Kerr (1936, pp. 156-157).

Distribution. The Rincon Shale crops out along the southern foothills of the Santa Ynez Range as a strip, locally broken by faulting, from the hills north of Summerland westward to and beyond the western border of the map area. From this strip the Rincon Shale dips under the coastal plain, but crops out again in the hills west of Santa Barbara where they are eroded through by San Roque Canyon.

On the north side of the Santa Ynez Range the Rincon Shale is exposed as a strip, from Hilton Canyon south of east for 6 miles to the mouth of Hot Springs Canyon. It again crops out as a narrow strip from 1 to 2½ miles west of Gibraltar Dam. The Rincon Shale is not known to be anywhere in the area north of the Santa Ynez River.

Topographic expression. The Rincon Shale disintegrates into small speroidal fragments and weathers to a dark loamy soil that supports grasses rather than brush. This formation thereby erodes and weathers to low, rounded, grass-covered hills that contrast sharply with the more rugged, brush-covered hills formed by the underlying Vaqueros Sandstone.

Thickness. Throughout the coastal area south of the Santa Ynez Range, the Rincon Shale is about 1600 feet in thickness, with variations ranging from 1450 to 1750 feet. On the north side of the range the Rincon is much thinner. Within the Santa Ynez fault zone near the head of Hilton Canyon, roughly 1000 feet of this formation crops out. North of the fault between Hilton and Hot Springs Canyons, the Rincon is about 1000 feet thick; in the area west of Gibraltar Dam it is about 500 feet thick and thins to the east.

Lithology. The Rincon Shale where freshly exposed is blue-gray, massive to poorly bedded, compact, moderately hard, argillaceous to silty, finely micaceous. Where weathered it is gray or light gray-brown, and characterized by close ellipsoidal or spheroidal fracture. A few layers are finely sandy; others bentonitic or tuffaceous; and some are harder and semi-siliceous. The clay-shale contains remains of marine life such as fish scales, foraminifera, radiolaria and sponge spicules. Within the shale are a few lentils or layers, up to 15 inches in thickness, of hard, gray to yellowish gray, impure dolomite, that weathers ochre-yellow on the surface. This rock also occurs as ellipsoidal or spheroidal concretions roughly a foot in diameter. These are found either singly, or as groups along certain horizons within the shale.

Photo 16. Rincon Shale, overturned southward (to right) and broken by landsliding at upper left. East side of Sycamore Canyon.

Lentils of fine grained, massive, light gray sandstone with concretions are present in the Rincon Shale only in areas north of the Santa Ynez fault.

Stratigraphy. On the south side of the Santa Ynez Range the Rincon is composed almost entirely of clay shale as described above. It rests conformably on the Vaqueros Sandstone with a generally abrupt, easily mappable contact. The basal part of the Rincon commonly contains thin layers with green grains of glauconite; also some pyrite, locally. Thin layers of gray bentonite up to an inch or two in thickness have been seen at a few places at various horizons in the Rincon. In the middle part of the formation, and roughly 300 feet apart, are two layers about 50 feet thick of harder semi-siliceous shale that weathers light brown or tan. These two layers form rather prominent exposures within otherwise poorly exposed clay shale, especially in the area northwest of Goleta Valley. In that area each contains layers up to 4 inches thick of hard, brown, platy, siliceous shale that weathers white. The Rincon Shale is overlain conformably by a layer of bentonite that forms the base of the Monterey shale.

On the north side of the Santa Ynez Range, the Rincon exposed between branches of the Santa Ynez fault near the head of Hilton Canyon is all clay shale, as on the south side of the range, and lies with an abrupt, conformable contact on the Vaqueros Sandstone. The upper part of the Rincon of this section is eroded away.

North of the Santa Ynez fault, in the exposure between Hilton and Hot Spring Canyons, the Rincon is composed of clay shale and siltstone. The middle portion contains one or two poorly exposed lentils of concretionary, fine grained sandstone that is similar to that of the underlying Vaqueros. These lentils reach a thickness of as much as 30 feet. In this section the Rincon Shale is overlain conformably by the "Temblor" sandstone and basal bentonite.

In the Santa Ynez River area west of Gibraltar Dam, the Rincon consists of clay shale that grades eastward along strike into siltstone. It grades downward into the Vaqueros Sandstone, and is conformably overlain by the "Temblor" Sandstone. In the western part of the exposure the clay shale contains several interbeds of soft to hard thin bedded semi-siliceous shale. Lentils of fine grained concretionary sandstone appear in the middle part of the siltstone and thicken eastward along strike. Eastward the entire section thins somewhat, and also grades laterally into sandstone undifferentiable from the sandstone of the underlying Vaqueros and overlying "Temblor."

Conditions of deposition. The abundant microscopic remains of organisms in the Rincon indicate that it accumulated on the bottom of a sea; genera of Foraminifera such as *Plectofrondicularia, Uvigerina* and *Uvigerinella* indicate, according to Kleinpell (1938, p. 115), moderately deep water conditions. Tropical and subtropical temperature is suggested by species such as *Siphogenerina transversa.*

The Rincon Shale accumulated as mud on the floor of the lower Miocene sea as it deepened following its transgressive advance during Vaqueros time. During Rincon time the lower Miocene sea encroached only to the margins of the old San Rafael uplift north of the present Santa Ynez River, as suggested by the absence of the Rincon in that area. The shore line of this sea must have followed the approximate site of the Santa Ynez River between Blue Canyon and the mouth of Tequepis Canyon, thence eastward from the former canyon and southwestward from the latter to and along the site of the Santa Ynez fault. This is suggested by the absence of Rincon sediments north of that line, and by the eastward thinning and gradation into sandstone near Gibraltar Dam.

The absence of sandstone in the Rincon, except near its northern limits, suggests that the San Rafael uplift to the north of the lower Miocene sea became eroded down to low relief during Rincon time and shed little material into the sea.

Age and correlation. The lower third of the Rincon Shale carries a foraminiferal fauna referred to as the *Uvigerinella sparsicostata* zone by Kleinpell (1938, pp. 111–112) which he assigns to the upper Zemorrian stage. The middle third contains at least two foraminiferal faunizones, of which the lower is referred to by Kleinpell (1938, p. 116) as the *Siphogenerina transversa* zone and the upper as the *Plectofrondicularia miocenica* zone; both of these he assigns to the lower Saucesian stage. The upper third of the Rincon contains a faunizone referred to by Kleinpell (1938, p. 116) as the *Uvigerinella obesa* zone, which he assigns to the upper Saucesian stage. Kleinpell (1938, fig. 14) assigns both the Zemorrian and Saucesian stages of California to the Oligocene epoch, but they are generally regarded as lower Miocene.

The four faunizones mentioned above are recognizable in the Rincon Shale practically throughout the area south of the Santa Ynez Range, and—with some minor variations—on the north side in the section about a mile east of Tequepis Canyon.

"Temblor" Sandstone

Usage of name. A lower Miocene sandstone that is younger than the Vaqueros and Rincon Formations crops out in several areas north of the Santa Ynez fault. This sandstone was mapped with the Vaqueros Sandstone by Kew (1919, pp. 13–15, map). It was later

referred to the Temblor by Nelson (1925, pp. 359–363, map) because it contains a *Turritella ocoyana* molluscan fauna that is characteristic of the Temblor Formation, as then regarded by California stratigraphers and later by the U. S. Geological Survey (Wilmarth, 1938, p. 2127), rather than the *Turritella ynezana* fauna that characterizes the Vaqueros Formation. Nelson's usage of the term Temblor is thereby retained in this report, but in quotes, because the type Temblor Formation at Carneros Canyon in the Temblor Range, Kern County, where it was first described by F. M. Anderson (1905, pp. 168–187) includes in its lower part beds correlative with the type Vaqueros.

Distribution. The "Temblor" sandstone crops out discontinuously for about 7 miles in the steeply north-dipping Miocene section between Hilton Canyon and the mouth of Hot Spring Canyon. Farther east it is prominently exposed in the folded Miocene sequence exposed from Blue Canyon northwest to the high hills east of lower Oso Canyon. It again crops out as a thin band across lower Redrock Canyon and on the east side of Loma Alta. Other exposures of this sandstone occur on the flanks of the Mono syncline east of Mono Creek. The "Temblor" sandstone crops out conspicuously along the steep southwestern slope of Little Pine Mountain ridge, as mapped by Nelson (1925).

Topographic expression. The "Temblor" sandstone erodes and weathers in the same manner as does the Vaqueros Sandstone. The thicker, massive, and more calcareous beds from bold outcrops, ledges, and strike ridges, while the intervening more friable layers are eroded down to depressions. The "Temblor" sandstone supports a heavy growth of brush.

Lithology, thickness and stratigraphy. The "Temblor" sandstone is of highly variable thickness and lithology. It is really a basal sandstone facies of the Monterey Shale in the area north of the Santa Ynez fault, and is not everywhere present.

In the area between Hilton Canyon and the mouth of Hot Spring Canyon the "Temblor" sandstone lies conformably on the Rincon Shale and ranges from about 10 to about 200 feet in thickness, averaging about 100 feet. In this area the sandstone is buff to light greenish-gray, friable to moderately hard, bedded to massive, medium to fine grained, arkosic. In some places, such as at and near Hot Spring Canyon, it contains concretions up to 10 inches in diameter. In most places the upper part is fine grained, locally calcareous, and tends to weather to various shades of cream white, ochre, orange, or even red. In many places, especially in the vicinity of Tequepis and Hilton Canyons, the sandstone contains scattered shells of *Pecten (Amusium) lompocensis* and other molluscs. Scattered pebbles occur locally. At several places the sandstone contains, near the base, a layer up to 15 feet in thickness of bentonite or bentonitic white tuff. This tuffaceous layer is exposed on the now abandoned highway half a mile west of Rancho San Fernando Rey, and also crops out half a mile west of Hilton Canyon.

West of Hilton Canyon the "Temblor" sandstone overlaps a minor north-trending fault. West of this fault the sandstone rests directly on Sespe conglomerate; it pinches out half a mile to the west.

In the vicinity of the Santa Barbara Reservoir, or in the area between Blue Canyon and the Santa Ynez River 2½ miles west of Gibraltar Dam, the "Temblor" sandstone is about 600 feet thick; but it thins to about 50 feet in the westernmost part of this exposure. The sandstone lies conformably on the Rincon Shale and Vaqueros Sandstone. The "Temblor" sandstone of this area is light gray, but weathers to buff; moderately hard, thick bedded, fine to coarse grained, arkosic, and locally calcareous. The lower half is pebbly, and in the eastern part of the area contains interbedded conglomerate, in which are semi-rounded, commonly polished pebbles and cobbles. Most of these are Franciscan varicolored cherts and jaspers, but some are dark sandstone, quartzite, and hard igneous rocks. The upper half of the "Temblor" is composed of well bedded sandstone, minor thin interbeds of shaly siltstone, and a few lentils of pebble conglomerate. Near the top of the "Temblor" sandstone exposed south and west of Gibraltar Dam is a prominent, hard, white bed of impure algal limestone, which ranges up to 10 feet in thickness. It is remarkably similar to the Eocene Sierra Blanca Limestone exposed in the Mono syncline east of the Santa Barbara Reservoir. Nelson (1925, p. 362) thought these two limestones to be identical. The limestone bed near Gibraltar Dam is overlain by about 50 feet of blue-gray, fine-grained, bedded sandstone, that is in turn overlain conformably by dark bluish brown shales of the Monterey. Molluscan fossils are common and locally abundant almost throughout the "Temblor" of this area.

In the hills east of Oso Canyon the "Temblor" sandstone is about 400 feet thick, is fossiliferous, and is of the same lithology as the nearby exposure to the southeast, except that the limestone near the top is not present. Within a mile of Oso Canyon the sandstone lies accordantly on the Sespe conglomerate, but to the southeast it lies unconformably on Eocene shale.

In the lower Oso Canyon the "Temblor" is represented by only a few feet of hard, calcareous, fine grained sandstone, at the base of the up-ended Monterey Shale; it lies unconformably on the Franciscan. Along strike to the west the "Temblor" sandstone

thickens to about 50 feet where it crosses lower Redrock Canyon. On the steep east side of Loma Alta, the "Temblor" sandstone is about 100 feet thick, rests on about 100 feet of brown Sespe (?) conglomerate, and is well bedded, buff, medium to fine grained, and fossiliferous, as in the hills east of Oso Canyon.

In the Mono syncline east of Mono Creek the "Temblor" sandstone is from 20 to 400 feet thick and lies on Eocene shale with little or no angular discordance. The "Temblor" is here composed of massive to bedded, buff, friable, fine- to medium-grained, unfossiliferous sandstone. West of Mono Creek this sandstone is absent.

On the south side of Little Pine Mountain north of Camuesa Canyon, the "Temblor" sandstone is from 100 to 200 feet thick, and is interbedded with shaly siltstone. It rests unconformably on Cretaceous shale, and grades upward into the Monterey Shale.

Conditions of deposition. The "Temblor" sandstone was deposited as the Miocene sea transgressed completely over the old San Rafael uplift. The sandstone, probably derived from erosion of the old San Rafael uplift, was sorted by waves and currents, and deposited in shallow water. The abundance of large molluscs such as the large pectens and gastropods suggest tropical or subtropical temperature.

Age and correlation. At a locality about half a mile west of Hilton Canyon the "Temblor" sandstone has yielded the following diagnostic moluscan species:

Pecten (Amusium) lompocensis Arnold
Pecten (Lyropecten) estrellanus Conrad
Pecten bowersi
Turritella ocoyana Conrad
Turritella temblorensis Wiedey

The above species, with the exception of *T. temblorensis*, occur at many localities in the "Temblor" sandstone exposed in the area between Blue Canyon and the Santa Ynez River west of Gibraltar Dam; at the Santa Barbara Reservoir; in the hills east of Oso Canyon; and on Loma Alta. There are, in addition, several undetermined fossil species at several of these localities.

The above fauna is characteristic of the "Temblor" sandstone mapped in the California Coast Ranges and indicates uppermost lower or middle Miocene age. The presence of bentonite and tuff in the "Temblor" sandstone in the area between Hilton and Hot Springs Canyons definitely correlates it with the bentonite horizon at the base of the Monterey Shale of the coastal area, and also with the Tranquillon Volcanics and tuff at the base of the Monterey Shale in the western Santa Ynez Mountains (Dibblee, 1950, pp. 33–34, pl. 1).

In the area east of Tequepis Canyon, foraminifers from shale below and above the "Temblor" sandstone indicate it to be near the top of the *Uvigerinella obesa* zone of Kleinpell (1938, p. 116), or of uppermost Saucesian age. A similar age is indicated for the bentonite horizon at the base of the Monterey Shale of the coastal area.

Monterey Shale

Type locality. The Miocene Monterey Shale, was first described by Blake (1856), who examined exposures 2 miles southeast of the town of Monterey, Monterey County. The Monterey is a very distinctive stratigraphic unit composed largely of thin bedded siliceous shale that is distributed extensively in the California Coast Ranges region.

Distribution. The Monterey Shale crops out in areas on both sides of the Santa Ynez range. On the south side, it crops out mainly along the coast, notably southeast of Carpinteria, and along much of the coastline from Santa Barbara westward; it is also prominent in some of the hills adjacent to the coast, such as those west of Santa Barbara and west of Elwood. Other exposures of Monterey Shale occur in the foothills north and northeast of the city of Santa Barbara, and north of Goleta Valley.

North of the Santa Ynez Range, the Monterey Shale crops out mainly along the vicinity of the Santa Ynez River, from the western border of the map area eastward to the mouth of Los Laureles Creek; and from Loma Alta and the hills east of Oso Canyon southeastward to Blue Canyon. The Monterey Shale is infolded in the Mono syncline that crosses lower Mono Canyon. The northern part of the map area includes a large exposure of Monterey Shale that forms the ridge of Little Pine Mountain.

Photo 17. Siliceous Monterey Shale. Roadcut in Tequepis Canyon, north side of Santa Ynez Mountains.

Topographic expression. The Monterey Shale is moderately resistant to weathering and erosion, and exposures form hills characterized by steep sides but rounded crests. Where cut into by waves or streams the shale forms prominent cliffs. In the hills the softer shales weather to a dark gray adobe soil that supports grasses. The harder siliceous shales form prominent outcrops, disintegrate to small platy fragments, and form little or no soil. They support grasses generally, except on steep north slopes where they support dense brush or scrubby oak timber.

Thickness. In the coastal area the thickness of the Monterey Shale ranges from about 1300 feet at the western border of the map area, to about 2300 feet in the hills west of Santa Barbara. In areas farther east the upper part is eroded away. In the Santa Ynez River area below the mouth of Los Laureles Canyon the Monterey Shale is from 1800 to 2500 feet thick, averaging of about 2200 feet. At Redrock Canyon it is about 1800 feet thick. In areas east of Redrock Canyon, the section of the Monterey Shale is incomplete: the upper beds are eroded away.

Stratigraphic relations. In the coastal area, the Monterey Shale rests conformably on the Rincon Shale, and is overlain by the Sisquoc Formation. In areas north of the Santa Ynez range, the Monterey Shale lies conformably or even gradationally on the "Temblor" sandstone; but where this is missing, it lies unconformably on formations ranging from Sespe to Franciscan, and is overlain conformably by the Sisquoc diatomite or Tequepis Sandstone.

On both sides of the Santa Ynez range the Monterey Shale is divisible into two parts that in most places are lithologically distinct, as in the western Santa Ynez Mountain area (Dibblee, 1950, p. 35). These are the lower Monterey, composed mostly of soft fissile to punky shale, and the upper Monterey, composed of hard siliceous shale. However, there is no definite dividing line between these units; the interval between is highly transitional, and the two units are not everywhere differentiable with certainty without adequate microfaunal control.

Lithology and stratigraphy in coastal area. On the coastal area the base of the Monterey Shale is marked by a layer of about 30 feet (maximum thickness) of soft white tuff, generally altered to bentonite or white clay, that is present only locally and rests on the Rincon Shale. Because of its softness this bentonite does not crop out, and appears only faintly in residual clayey soil.

The lower Monterey Shale of the coastal area is from 800 to 1100 feet in thickness and is composed predominantly of soft, fissile, punky, organic shale, and a lesser amount of interbedded hard siliceous shale, calcareous shale, and thin limestone layers. When fresh, all the shales are finely laminated and dark brown in color; they commonly emit a faint petroliferous odor. Where weathered, they are bleached light buff to cream-white. The punky organic shales contain a great abundance of fish scales, and tests of foraminifers, diatoms, and other microscopic marine organisms. Calcium phosphate in the form of buff-colored laminae or minute lenses is abundant in the punky shale of the upper part of the lower Monterey Shale. Hard, porcelaneous siliceous shale forms local facies within the punky organic shale, and some of the siliceous shale contain laminae of dark chalcedonic chert. Creamy gray limestone occurs as occasional to frequent interbeds up to a foot thick in the soft punky shales. Very fine gray tuff and bentonite occur locally in the shale, as laminae or layers a few millimeters thick.

On the sea cliff near the mouth of Dos Pueblos Canyon, is a lentil of shale breccia about 115 feet thick. It is in the lower Monterey Shale, about 400 feet above its base (see section shown in Kleinpell 1938, fig. 6). This is the only known shale breccia within the lower Monterey Shale of this district.

The transitional beds between the lower and upper Monterey Shale consist of thinly laminared punky shales with abundant buff phosphatic laminae, and interbeds of hard brittle siliceous shale.

The upper Monterey Shale of the coastal area ranges in thickness from 500 to 1400 feet, averaging about 800 feet. It consists of hard, brittle, porcelaneous, siliceous shale that grades upward into less brittle, semi-punky, somewhat silty siliceous shale. All of this shale is finely laminated, and fractures along bedding planes into platy slabs from an inch or less to 4 inches thick. When fresh, the shale is dark brown; but it bleaches light gray to white on the surface. Soft, argillaceous, locally phosphatic shale occurs as thin partings and occasional interbeds up to a foot or two in thickness between the platy siliceous layers. The brittle porcelaneous siliceous beds in the lower part of the upper Monterey locally contain laminae of dark chalcedonic chert, but this is never abundant here as it is in the western Santa Ynez Mountains. Creamy gray limestone occurs sparingly in this unit, and only as an occasional layer up to a foot thick.

The upper Monterey Shale of the coastal area is highly organic, containing remains of microscopic marine life. Most of this material is probably diatom debris, and it may constitute a large proportion of the siliceous shales. Besides the larger diatoms, fish scales and arenaceous foraminifers are abundant, but calcareous foraminifers that are so abundant in the lower Monterey are scarce in the upper Monterey Shale. The siliceous shales of the upper Monterey are gen-

erally bituminous, as a petroliferous odor can almost always be detected on freshly broken surfaces; their dark brown color is probably imparted from bituminous material. On the beaches a black tarry residue is generally present in fracture surfaces, or in the shale where it has been brecciated along minor faults.

The lower and upper parts of the Monterey Shale are not readily differentiable on the coastal area, but the general distribution of these two units is about as indicated below. The lower Monterey includes all the Monterey Shale exposed in the foothills northeast and north of the town of Santa Barbara; north and northwest of Goleta Valley; in the hills west of Santa Barbara; and on the sea cliffs eastward from the mouth of San Roque Canyon. It also includes part of the Monterey Shale exposed in the sea cliffs near the mouth of Dos Pueblos canyon and westward, and at Elwood oil field. The upper Monterey Shale crops out in the sea cliffs just east of the mouth of Dos Pueblos Creek; southeast of Elwood oil field; from the University of California Santa Barbara college campus near Goleta slough eastward along the sea cliffs to the mouth of San Roque Creek; and in the sea cliffs southeast of Carpinteria.

Lithology and stratigraphy in Santa Ynez River area. In the Santa Ynez River area westward from the mouth of Los Laureles Canyon the lower Monterey Shale is from 600 to 900 feet thick, and consists of poorly exposed soft, faintly bedded to fissile argillaceous shale. It locally contains thin laminae of bentonite, and in the upper portion contains phosphatic laminae. Limestone occurs as an occasional bed up to a foot thick. This shale contains abundant foraminifers and fish scales.

In the Santa Ynez River area from Blue Canyon northwestward to Loma Alta, and on Little Pine Mountain, the lower Monterey Shale is from 300 to 600 feet thick and consists of soft argillaceous to semipunky fissile brown shale, and some thin interbeds up to a foot thick of creamy gray limestone. In the upper portion are interbeds of hard, brittle, siliceous shale. Fish scales and foraminifers are abundant in the softer shales.

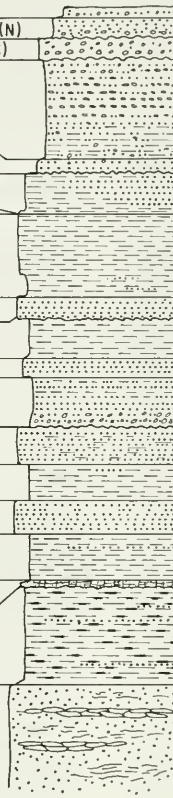
Throughout the Santa Ynez River area and on Little Pine Mountain the lower Monterey Shale grades into the upper Monterey through some 50 to 300 feet of transitional beds composed of thin bedded, laminated, soft, phosphatic brown shales and interbedded, laminated, brittle siliceous shales, as in the coastal area.

The upper Monterey Shale of these areas is about the same as in the coastal area, except that it is somewhat more siliceous and thicker, averaging about 2000 feet. The lower 300 to 600 feet of the upper Monterey consists of brown, laminated, hard, brittle, porcelaneous siliceous shale that locally contains cherty laminae. This grades upward into less siliceous, somewhat silty, platy brown shale that constitutes the remainder of the upper Monterey of this area. This in turn grades upward through about 200 feet of transitional splintery siltstone into the Tequepis Sandstone in the Santa Ynez River area, or into diatomite of the Sisquoc Formation near Cachuma Dam. The upper Monterey Shale of these areas is bituminous, and contains remains of the same type of marine life as does this unit in the coastal area.

In upper Hilton Canyon, on the north side of the north branch of the Santa Ynez fault is a remarkable exposure of about 200 feet of dense, light gray limestone that contains several layers of dark cherty shale. The limestone dips southward into the fault and rests unconformably on the Matilija (?) Sandstone. The limestone forms the basal part of the Monterey Shale of this area, and may belong to the basal part of the upper unit of the Monterey, because to the west, beyond the map area, the upper Monterey Shale rests directly on Cretaceous shale and serpentine (Dibblee, 1950, pl. 1), with the lower Monterey missing.

Conditions of deposition. The enormous amount of siliceous sediment that makes up the Monterey Shale, together with the tuffaceous material, calcareous and phosphatic sediments, and the many remains of microscopic marine life, indicates the Monterey Shale to have accumulated under unique conditions—conditions that were entirely different than those under which all the older formations accumulated. The Monterey Shale is essentially a series of chemical and chemical-organic sediments that accumulated in an open sea. The absence of clastic sediments (other than fine clays and silts) indicates that the nearby land masses or large rivers, which contributed the enormous amount of clastic sediment constituting all the older formations, failed to contribute them during Monterey time. Some genera of foraminifers in the lower Monterey Shale suggest moderate depth, open sea conditions, and waters of a more temperate aspect than that indicated by faunas of lower Miocene zones, according to Kleinpell (1938, pp. 120–124).

The marked difference of the Monterey sediments as compared to those of all the older formations indicate that a profound change occurred at the beginning of Monterey time in the Coast Ranges region. This took place in the form of violent volcanic outbursts in some nearby local areas, such as at the sites of the present Tranquillon Mountain of the western Santa Ynez range; the Nipomo area north of Santa Maria Valley; and at Santa Cruz Island, as indicated by the extensive volcanic and pyroclastic rocks at the base of the Monterey Shale in those areas. Within the map



Age		Formation	Thickness	Description
Quaternary	Recent	Alluvium (N)	0–50'	Gravel, sand, silt
	Pleistocene Upper	Older Alluvium (N)	0–100'	Gravel, sand
	Pleistocene Upper	Fanglomerate (N)	0–200'	Boulder gravel
	Pleistocene Lower	Paso Robles (N)	2500'	Light gray cobble gravel; shale, pebble gravel, pebbly gray clay, silt and sand
?	?			
Tertiary	Pliocene Upper	Careaga	0–270'	White to yellow sand
	Pliocene Lower ?	Tequepis	0–900'	Fine white sand, locally tuffaceous
		Sisquoc	0–900'	White silty diatomite
	Miocene Upper	Monterey	1300'–2500'	Hard laminate platy to fissile siliceous shale
	Miocene Middle			Soft fissile to ellipsoidal shale; occasional lentils of sandstone
	Miocene Middle	Temblor	0–600'	Buff sandstone; locally bentonitic
	Miocene Lower	Rincon	0–1000'	Gray clay shale; local sandstone
	Miocene Lower	Vaqueros	0–600'	Greenish buff sandstone
	? ?			
	Oligocene	Sespe (N)	0–2000'	Gray to buff sandstone; Green to red clays, silts; Basal red to gray conglomerate
	Eocene Upper	Coldwater	0–1500'	Buff arkosic sandstone
	Eocene Upper	Cozy Dell	0–1200'	Gray clay shale
	?	Matilija	0–800'	Buff arkosic sandstone
	Eocene Middle ?	Juncal	0–1500'	Gray clay shale and siltstone
		Sierra Blanca	0–20'	White sandy limestone
Cretaceous	Lower	Espada	2000'	Dark green-brown carbonaceous shale and thin interbeds of green-brown fine sandstone
?				CONTACT NOT EXPOSED
Cretaceous or Upper Jurassic ?		Franciscan	2000'	Dark green-gray sandstone or graywacke; sheared gray-black clay shale; varicolored chert

(N) Non-marine formation; all others marine

Figure 7. Stratigraphic column of Santa Ynez River area between Santa Ynez and Little Pine Faults, Santa Barbara County, California.

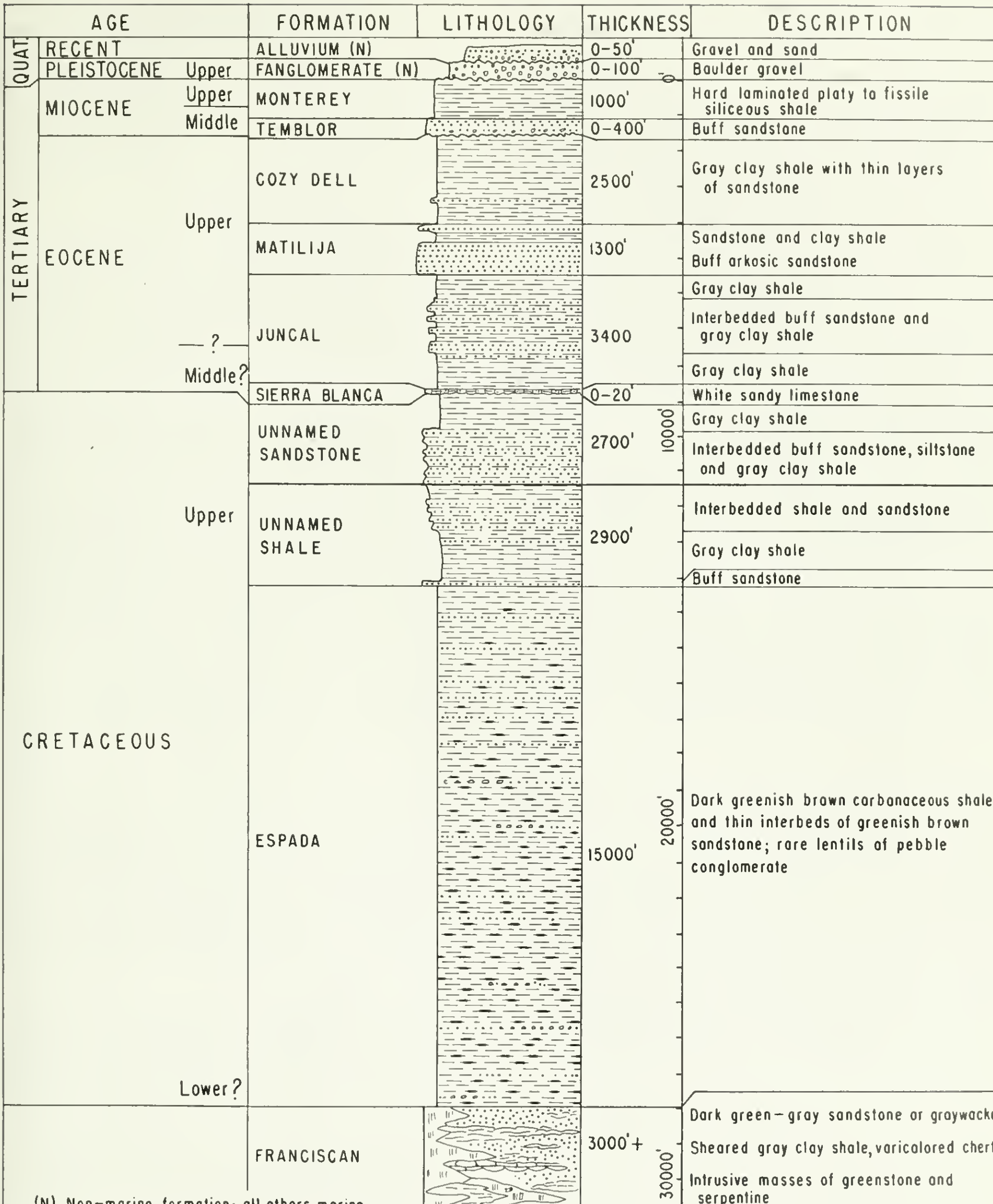


Figure 8. Stratigraphic column of area northeast of Little Pine fault and Blue Canyon, Santa Barbara County, California.

area volcanic ash from these volcanic outbursts settled on the sea floor, and is now represented by bentonite, an alteration product of volcanic ash or tuff, at the base of the Monterey Shale. This volcanic disturbance was accompanied by submergence of previously existing land masses, such as the San Rafael uplift north of the present Santa Ynez River, so that the entire map area then became part of a widespread, open sea, under which the Monterey Shale accumulated.

The lower Monterey Shale was deposited as fine argillaceous muds admixed with occasional, thin layers of fine volcanic ash, and varying quantities of siliceous, calcareous and phosphatic material, along with remains of abundant microscopic marine organisms, mostly calcareous foraminifers. The upper part of the Monterey Shale was deposited largely as siliceous sediments, and minor clay and silt, and abundant remains of siliceous microorganisms, mostly diatom tests and arenaceous foraminifers.

The source of the silica that constitutes such a large proportion of the Monterey Shale is not definitely known. The presence of tuffaceous material throughout the Monterey Shale suggests a volcanic source, in which the silica was derived either from alteration of volcanic ash in the sea water, or from hydrous silicates and silicic acid from solutions that emanated from submarine volcanic vents, as concluded by Taliaferro (1933, p. 54). Most of the silica was precipitated inorganically, probably as a colloidal ooze, but some was precipitated by microscopic organisms, such as diatoms and radiolaria.

The unusually large amount of silica plus the appreciable amounts of calcium carbonate and calcium phosphate introduced into the sea water, together with other unknown factors, brought about extremely favorable conditions for marine life, especially microscopic organisms, which must have flourished as never before. This is indicated by the extreme abundance of tests of foraminifers, diatoms, and radiolarians, spicules of sponges, and scales of fish. Further evidence of prolific marine life in the middle and late Miocene seas is the petroleum that almost everywhere impregnates these shales to some degree where fresh—if this was derived from an abundance of organic material entrapped in these sediments.

Age and correlation. The lower Monterey Shale in most places contains a prolific assemblage of calcareous foraminifers in which there are several faunizones or substages as recognized throughout the Coast Range region by Kleinpell (1938, pp. 117–130). These faunas indicate the lower Monterey Shale to be in the Relizian and Luisian Stages of Kleinpell (1938), middle Miocene. The traditional beds between the

Age of the Monterey Shale.

	Zone	Stage	Age
Upper Monterey Shale	*Bulimina hughesi* (poor faunas).	U. Mohnian	Upper Miocene
Transition beds	*Bulimina uvigeriniformis.* *Bolivina modeloensis.*	L. Mohnian	Upper Miocene
Lower Monterey Shale	*Siphogenerina collomi—Valvalineria californica.* *Siphogenerina nuciformis* and *S. reedi.*	Luisian	Middle Miocene
Lower Monterey Shale	*Siphogenerina branneri—Valvulineria depressa.* *Siphogenerina hughesi.*	Relizian	Middle Miocene

lower and upper Monterey Shale contain a foraminiferal zone indicative of the lower Mohnian stage, lowest upper Miocene.

The upper Monterey Shale contains numerous crushed diatom remains, radiolaria and unidentifiable arenaceous foraminifers. The lower beds contain a very meagre assemblage of calcareous foraminifers indicative of the upper Mohnian stage, upper Miocene. The upper beds are practically devoid of calcareous foraminifers and are either in the upper Mohnian or lower Delmontian stages, upper Miocene.

On both sides of the Santa Ynez Range the following foraminiferal zones and stages of Kleinpell (1938, pp. 117–130) are recognizable in almost any good surface or cored drillhole section of Monterey Shale, although some zones are locally very thin or missing.

The basal part of the Monterey Shale in some sections—that is, as much as several hundred feet of beds above the basal bentonite—contains foraminifers of the *Uvigerinella obesa* zone of the Saucesian stage. For this reason some stratigraphers prefer to assign these beds and the bentonite bed to the Rincon rather than the Monterey Shale, despite the lithologic change at the base of the bentonite.

Some stratigraphers prefer to restrict the Monterey Shale of the coastal area to the lower part, or that containing the Relizian and Luisian foraminiferal faunas, and assign the overlying part with the Mohnian faunas to the overlying "Santa Margarita shale". This was done by Redwine et al. (1952), because of suggestive evidence of a possible unconformity at the base of the Mohnian shale in subsurface sections in the Coal Oil Point-Goleta Valley area. However, this arrangement does not conform to that followed in areas north and west of the map area, in which all the distinctive organic and siliceous shale, including all the shale of Mohnian age, is known and mapped

as the Monterey Shale by Woodring and Bramlette (1950) and Dibblee (1950, pp. 34–42). Also, the type Santa Margarita Formation of Fairbanks (1904) is sandstone, not shale, and even though part of the Monterey Shale at this district may be correlative with it, the name Santa Margarita cannot properly be applied to a shale unit.

Sisquoc Formation

Type locality. The Sisquoc Formation—exposures of about 1100 feet of diatomite, siltstone, and sandstone of Pliocene age south of the Sisquoc River about a mile east of the mouth of Foxen Canyon, 10 miles southeast of Santa Maria—was first described by Porter (1932, pp. 135–143). Unfortunately, it is an incomplete section, being largely a marginal sandstone facies (called Tinaquaic Sandstone Member by Woodring and Bramlette, 1950, pp. 26–36). The basinward claystone facies of the Sisquoc Formation has been described and mapped in the Casmalia and Purisima Hills by Woodring and Bramlette (1950, pp. 26–36) and in the hills south of Lompoc and Santa Ynez Valleys by the writer (Dibblee, 1950, pp. 43–45), where it is composed of several thousand feet of diatomite and diatomaceous claystone overlying the Monterey shale.

Distribution. The Sisquoc Formation crops out as a narrow strip in the hills north of the Cachuma Reservoir, where it consists of diatomite that grades laterally eastward into the Tequepis Sandstone. This diatomite also crops out as small isolated exposures south of the Santa Ynez River opposite the mouth of Santa Cruz Creek.

Diatomaceous shale generally known as the "Santa Margarita shale", but here included in the Sisquoc Formation, crops out at several places on the coastal bluffs south and west of Goleta. These places are just east of Goleta gas field; at the University of California Santa Barbara campus westerly to and beyond Coal Oil Point; and on Naples bluff a mile west of Elwood oil field.

Topographic expression. The Sisquoc Formation is weakly resistant to erosion and north of the Santa Ynez River erodes to low subdued topography. It forms a poor, light gray soil that supports grasses. On the coastal area the Sisquoc Formation is exposed only on wave-cut sea cliffs.

Lithology and stratigraphy in Santa Ynez River area. The Sisquoc Formation exposed in the hills northwest and north of the Cachuma Reservoir is about 900 feet in thickness, grades downward into the Monterey Shale, and is overlain unconformably by the Careaga Sandstone. The Sisquoc of this area is of the same lithology as in Santa Ynez Valley to the west, where it is composed of soft, punky, white, faintly laminated, fissile to massive blocky diatomite. North of Cachuma Reservoir the diatomite is ruffaceous, containing fragments of volcanic glass. This diatomite grades laterally eastward through massive brownish-gray diatomaceous and tuffaceous siltstone into the Tequepis fine whire sandstone. However, the upper 200 feet of the diatomite persists eastward above this sandstone for several miles, then is overlapped by the Careaga Sandstone near Santa Cruz Creek.

In the exposures south of the Santa Ynez River, opposite the mouth of Santa Cruz Creek, the Sisquoc is composed of about 300 feet of white, soft, punky, thin-bedded, laminated, fissile diatomite that grades downward into the Monterey Shale and is overlapped by the Careaga Sandstone.

Lithology and stratigraphy in coastal area. In the coastal area the Sisquoc (or "Santa Margarita") shale formation lies with an abrupt, disconformable contact on the upper Monterey Shale in some places, and a somewhat gradational contact in others. There is no complete section exposed, as the upper part of the formation is eroded away. On the sea cliff east of Goleta gas field the Sisquoc shale is overlain unconformably by upper Pliocene fine sandstone.

The greatest outcrop thicknesses of the Sisquoc Formation are a section exposed a mile northwest of, and another section 2½ miles east of, Coal Oil Point. Both these sections expose the lower 1000 feet of this formation. At Naples Bluff the lower 700 feet is exposed; and at the bluff east of Goleta gas field, the lower 800 feet.

East of Goleta gas field, the base of the Sisquoc Formation consists of about 150 feet of shale breccia resting with a slight angular unconformity on the upper Monterey Shale. This basal breccia is composed of unsorted angular fragments of Monterey siliceous shale embedded in a massive siltstone matrix. The shale fragments average about 4 inches in longest dimension, but some are as large as 2 feet. At Naples bluff, just west of Elwood oil field, is a lentil of shale breccia about 300 feet in maximum thickness, which is exactly similar to that east of Goleta gas field. It lies at, or possibly just below, the base of the Sisquoc shale. Elsewhere there is no shale breccia at the base of the Sisquoc.

The lower 500 to 800 feet of the Sisquoc consists of gray-brown, moderately to faintly laminated, semi-siliceous to diatomaceous clay shale or siltstone that disintegrates into splintery fragments. Southeast of Elwood oil field this part of the Sisquoc is soft laminated fissile diatomaceous shale that weathers nearly white. This lower shale grades upward into the remainder of the exposed Sisquoc Formation that con-

sists of soft, light brown-gray, faintly laminated to massive claystone or diatomaceous siltstone that disintegrates into small spheroidal fragments. Throughout the Sisquoc Formation are nodules or lentils of ochre-yellow ferruginous dolomite as much as a foot or two in thickness.

Organic remains in the Sisquoc consist mainly of crushed diatom debris, and some arenaceous foraminifers, radiolarians, sponge spicules, and fish scales. Calcareous foraminifers are scarce.

Conditions of deposition. The Sisquoc Formation was deposited as fine diatomaceous mud under a generally open sea that persisted from Monterey time, as regional subsidence continued. Lentils of shale breccia at the base of the Sisquoc suggests local disturbances took place at the beginning of Sisquoc time, causing local uplifts and erosion of the top of the Monterey Shale. The major unconformity at the base of the Sisquoc Formation in areas north of the Santa Ynez Valley indicates that the first uplift of the present San Rafael Mountain region may have happened during this disturbance. It is possible also that the present Santa Ynez Range may also have undergone its first uplift at this time, as suggested not only by the lentils of shale breccia at the base of the Sisquoc, but by the fact that the Sisquoc Formation is composed mainly of diatomite north of this range, and clay shale south of it. While it cannot be proved that the range ever emerged from the sea during this disturbance, it might have existed as a submarine barrier between the area to the north and the area to the south.

In the area north of the present Santa Ynez Range the Sisquoc Formation accumulated in a shallow sea as fine diatomaceous mud. In this sea, diatoms must have flourished profusely; for countless numbers of minute tests of these one-celled plants and other organic remains accumulated on the sea floor, along with minor amounts of clay.

In the area south of the present Santa Ynez Range the Sisquoc Formation accumulated mostly as clay and silt in a deeper open sea. Diatoms flourished in this sea also, but not so prolifically as in the shallow sea to the north, and their tests accumulated along with the clay and silt. Other forms of marine life that flourished in late Monterey time continued to flourish during Sisquoc time throughout the entire map area.

Age and correlation. On both sides of the Santa Ynez Range the formation mapped as Sisquoc contains abundant diatoms, radiolarians, siliceous sponge spicules, arenaceous foraminifers and fish scales; but nothing is yet known of their age significance. The formation is almost devoid of calcareous foraminifers, which at present are the only means of determining its age. In the Santa Ynez River area, the lower part of the Sisquoc has yielded *Buliminella elegantissima* and *Nonionella miocenica*—Foraminifera found in the diatomaceous claystone facies of the Sisquoc Formation of the Santa Maria basin, according to Woodring and Bramlette (1950, p. 35). On the coast the Sisquoc Formation contains a meagre foraminiferal fauna including *Bolivina obliqua*, a characteristic species of the Sisquoc Formation of the Purisima and Casmalia Hills and Santa Maria Valley oil field. The Sisquoc Formation of the Santa Maria basin is considered to range in age from late Miocene (Delmontian stage) to middle Pliocene by Woodring and Bramlette (1950, pp. 101–102, 106).

The Sisquoc diatomite facies, together with the Tequepis Sandstone facies into which it grades eastward, is probably correlative with only the lower part of the completely exposed 5,000-foot section of the Sisquoc Formation in the Purisima and Casmalia Hills.

On the coastal area the Sisquoc Formation as herein mapped is generally known by petroleum geologists as the "Santa Margarita" shale, because it lies above the Monterey Shale and below lower Pliocene sandstone farther east in in the Ventura region; probably it shall be correlated with the Santa Margarita Sandstone of San Luis Obispo County. However, the name "Santa Margarita" is a misnomer for this shale, for lithologically it is not like the type Santa Margarita of the Santa Margarita district, San Luis Obispo County. There, the Santa Margarita is a sandstone, as described by Fairbanks (1904). Therefore the name Santa Margarita cannot properly be used for this shale and diatomite formation within the map area.

The name Sisquoc has not been applied by geologists to the so called "Santa Margarita" shale of the coastal area because this shale or claystone unit is generally believed to be older than the Sisquoc Formation as mapped in areas north of the Santa Ynez Range (Bailey 1952, p. 177). It may be in part older than the type Sisquoc (or Tinaquaic Sandstone Member) of early Pliocene age in the Foxen Canyon area; that section is incomplete, as the lower beds are missing. On the coast, only the lower beds are exposed on shore. However, elsewhere in the Santa Maria basin, the Sisquoc Formation, mapped in the Casmalia, Purisima, Santa Rita, and Lompoc Hills by Woodring, and Bramlette (1950) and the writer (1950) consists of several thousand feet of diatomaceous claystone and diatomite of early Pliocene and late Miocene (Delmontian) ages that in most places rests conformably on Monterey siliceous shale of late Mohnian age. There is little doubt, in the writer's opinion, that the so called "Santa Margarita" diatomaceous shale of the coastal

area, including that of the Point Conception area described (as Sisquoc) by the writer (Dibblee 1950, pp. 43-44), is the same unit as the Sisquoc in areas north of the Santa Ynez Range, because its general lithology and stratigraphic relations to the Monterey are similar. In fact, the "Santa Margarita" shale of the Point Conception and Coal Oil Point sections is almost lithologically identical with the Sisquoc Formation in some parts of the Purisima and Casmalia Hills. Also, the "Santa Margarita" shale south of the Santa Ynez Range, and the Sisquoc Formation north of it, contain a *Bolivina obliqua* foraminiferal fauna, according to Aden Hughes (oral communication, 1952). Therefore, on the basis of the foregoing evidence, the Sisquoc Formation and "Santa Margarita" shale are judged to be the same unit, and must once have been continuous. Therefore the writer sees no objection to applying the name Sisquoc to this unit on both sides of the Santa Ynez Range.

It is concluded that the Sisquoc Formation as mapped both in the Santa Ynez River and the coastal areas is probably of Delmontian age, late Miocene, and may be in part younger, possibly of early Pliocene age.

Tequepis Sandstone

Type locality. The Tequepis Sandstone was first described by Nelson (1925, pp. 367-368) for exposures of a sandstone unit that overlies the Monterey ("Salinas") Shale along the Santa Ynez River near its juncture with Santa Cruz and Cachuma Creeks, on the Tequepis Rancho. The Tequepis Sandstone grades laterally westward into the Sisquoc Formation as herein mapped.

Distribution and topographic expression. The Tequepis Sandstone crops out along the north side of the Santa Ynez River from the mouth of Cachuma Canyon eastward almost continuously to the mouth of Redrock Canyon. About a mile west of Cachuma Creek it grades laterally into diatomite of the Sisquoc Formation. Other exposures of the Tequepis Sandstone occur in Horse Canyon, as shown by Nelson (1925, map).

Along the Santa Ynez River area the Tequepis Sandstone dips steeply north and forms prominent white bluffs where cut into by the river. Back from the river the standstone forms low sandy hills and supports heavy brush.

Lithology and stratigraphy. At the type section of the Tequepis Sandstone, between the lower ends of Cachuma and Santa Cruz Creeks, the Tequepis Sandstone is about 900 feet thick and grades downward through about 200 feet of siltstone into the Monterey Shale. The sandstone here is overlain by about 100 feet of diatomite. Farther east, the Tequepis Sandstone gradually thins to about 500 feet at lower Redrock Canyon as the upper beds become overlapped by the Careaga Sandstone. The Tequepis Sandstone is gray-white, massive to thick-bedded, compact, semifriable, and very fine graded. At Cachuma and Santa Cruz Creeks, according to Nelson (1925, p. 367), "it is made up very largely of angular to subangular grains of

Photo 18. Exposure of Tequepis Sandstone in bluffs at right. Santa Ynez River east of mouth of Cachuma Canyon.

feldspar. . . . Both orthoclase and plagioclase feldspars are present. A few grains of microcline have been observed. Quartz grains are not a conspicuous constituent. The upper potrion of the member contains sporadic well-rounded pebbles of chert. With few exceptions these are all black." At Redrock Canyon, again according to Nelson (1925, p. 368), "it is a massive creamy-gray tuff which consist of angular grains of feldspar, fragments of volcanic glass and remains of diatoms. . . . West of Cachuma Creek the member likewise contains a considerable amount of glass."

Conditions of deposition. The Tequepis Sandstone was deposited in a portion of the Sisquoc sea probably close to shore, that must have been to the northeast, as indicated by the lateral gradation southwestward into diatomite. The land mass that supplied the sand must have been an area of granitic exposures, as indicated by the felspathic composition of the sand. The presence of volcanic glass in the sand indicates volcanic activity in some nearby areas during this time. The sand was well sorted by waves and currents.

Age and correlation. The Tequepis Sandstone is unfossiliferous, except for diatom debris and fish scales. To the west it grades into diatomite of the Sisquoc Formation, indicating that it is the same age as that formation, or the lower part of it that is Delmontian, upper Miocene, and possibly early Pliocene. The Tequepis Sandstone is quite similar to the Santa Margarita Sandstone of San Luis Obispo County, with which it probably correlates, except that the Santa Margarita Sandstone is coarser.

Careaga Sandstone

Type locality. The Careaga Sandstone was first described as the Careaga Formation by Wissler and Dreyer (1941, pp. 235-7), later as the Careaga Sandstone by Woodring, Bramlette and Lohman (1943, pp. 1355–8). (Not in bibliography, see AAPG v. 27, no. 10.) The exposures are marine sandstone of late Pliocene age on the north slope of the Purisima Hills 2 miles south of former Careaga station, 5 miles west of Los Alamos.

Distribution. The Careaga Sandstone crops out north of the Santa Ynez River almost continuously from the west border of the map area to Redrock Canyon. This sand was mapped and described by Nelson (1925, pp. 372–374) as the Fernando Formation. Several small exposures of the Careaga occur south of the Santa Ynez River opposite the mouths of Horse Canyon and Santa Cruz Creek.

Stratigraphy and lithology. The Careaga Sandstone rests unconformably upon the Sisquoc Formation and Tequepis Sandstone but with little or no visible discordance in the exposures north of the Santa Ynez River. However in exposures south of the river the Careaga Sandstone lies with angular discordance upon more steeply tilted Sisquoc, Monterey, and "Temblor" Formations. In all exposures the Careaga is conformably overlain by the Paso Robles Formation. North of the river, between Cachuma and Redrock Canyons, the Careaga Sandstone averages about 200 feet in thickness; it has a maximum thickness of 270 feet, and thins to the west to about 25 feet at the west border of the map area. South of the river this sand is from 20 to 50 feet thick.

The Careaga Sandstone is gray-white to light buff, poorly consolidated, massive, fine to medium grained, and composed of well sorted subrounded grains mostly of quartz. As in the Purisima Hills to the west, the Careaga Sandstone is in most places divisible into two members separated by a hard calcareous bed.

The upper member, about 100 feet thick, consists of gray-white medium grained sand. It contains in its upper part pebbles mostly of Monterey siliceous shale which locally are numerous, and in its lower part some molluscan fossils, mostly pelecypods.

The calcareous bed that separates the two members is as much as 10 feet thick and consists of gray-white hard calcareous sandstone or sandy limestone which is the only part of the Careaga that crops out prominently. This calcareous bed contains polished pebbles of quartzite, black chert, colored Franciscan chert and Monterey cherty shale, and also recrystallized calcite shells, including sand dollars, and casts of small gastropods.

The lower member, about 100 feet thick, consists of medium- to fine-grained, gray-white to buff sand which locally contains lentils a foot or two thick of fossil pelecypods. This member is not everywhere present, as it is missing within a mile of the western border of the district and south of the Santa Ynez River. In the latter area the calcareous bed is also missing or is not exposed.

Conditions of deposition. The Careaga Sandstone was deposited in waters of a shallow marine embayment that inundated the Santa Maria basin, that is, the wedge-shaped area between the San Rafael and Santa Ynez Mountains, during late Pliocene time. Deposition of this sand was preceded by an interval of emergence and erosion of both the Santa Ynez and San Rafael Mountain areas, as indicated by the angular unconformity at the base of the Careaga Sandstone south of the Santa Ynez River, and in the foothills of the San Rafael Mountains to the north where the Careaga lies unconformably on formations as old as Cretaceous. Within the intervening basin area north of the part of the Santa Ynez River between

Cachuma Dam and Redrock Canyon there was either uplift and erosion, or nondeposition, as indicated by the absence there of the several thousand feet of upper Sisquoc Formation and Foxen Formation that occur farther west in the Santa Maria basin.

The Careaga Sandstone was deposited in very shallow marine water, as indicated by the presence of sand dollars, oyster shells, and other shallow-water molluscs. South of the present Santa Ynez River the sands were deposited over an eroded surface of the northern margin of the Santa Ynez Mountain uplift as the marine embayment transgressed onto it. The upper part of the Careaga Sandstone that contains siliceous shale pebbles is probably a beach sand that was deposited as the marine embayment receded. This pebbly sand represents the final stage of marine deposition in the Santa Maria basin.

Age and correlation. Within the map area the Careaga Sandstone contains locally abundant shells of *Ostrea*, *Tivela*, and other pelecypods, as well as casts of small gastropods, but these are too poorly preserved or too thoroughly recrystallized to be readily identifiable. Many miles to the west in the Purisima Hills the Careaga Sandstone contains a large molluscan fauna that, according to Woodring and Bramlette (1950, pp. 102-106), indicates late Pliocene age.

The calcareous bed locally contains sand dollars identified as *Dendraster ashleyi* (Arnold). These too are common in upper Pliocene formations; the species is the same that occurs in the calcareous bed or "Dendraster reef" that separates the lower and upper members of the Careaga Sandstone on the north flank of the Purisima Hills.

"Pico" Formation

Distribution. Dark gray marine sandy siltstone of probable Pliocene age crops out only in the sea cliff just east of the Goleta gas field. It was described and mapped by Upson (1951, p. 15-16, pl. 2) as an unnamed Pliocene formation. It is lithologically similar to, and is believed to be equivalent to, some part of the Pico Formation as described and mapped in the Santa Clara Valley by Kew (1924) and later in the Ventura region by Putnam (1942, p. 1). This marine siltstone is therefore referred to the Pico Formation, but in quotes, as on shore it is not directly traceable into the Pico of the Ventura region.

Lithology and stratigraphic relations. The "Pico" siltstone rests unconformably on the Sisquoc and Monterey Shales, and the maximum exposed thickness is 330 feet; an unknown thickness of the upper portion has been removed by erosion. This siltstone is not known to be in contact with the supposedly younger Santa Barbara Formation, but if this siltstone exists under any part of Goleta Valley it may underlie that formation at depth.

The prominent exposure of the "Pico" siltstone in the sea cliff east of Goleta gas field is described by Upson (1951, p. 15). The sequence is as follows:

Sequence of "Pico" siltstone exposed in sea cliff in secs. 22 and 23, T. 4 N., R. 7 W., east of Goleta gas field.

	Thickness (feet)
Siltstone and fine sandstone, gray, compact, crudely stratified, with shale partings	50
Sandstone, white to gray, very fine to medium grained, friable, cross-bedded, with strata 2 inches to 2 feet thick separated by partings of dark clay. Grades laterally westward into coarse sand and gravel that forms a lense with abundant molluscan fossils at base	33
Siltstone or very fine sandstone, dark bluish gray, massive, compact, few scattered molluscan fossils	65
Siltstone, as above, with calcareous concretions as much as 1 foot thick and several feet long	6
Siltstone, or very fine sandstone, as above, few scattered molluscan fossils	63
Conglomerate, with angular fragments as much as several inches long of limestone	2
Siltstone, bluish gray, massive, compact, fine sandy, few scattered molluscan fossils	101
Conglomerate, with large angular slabs and blocks of limestone probably derived from limestone of Monterey Shale, and some of basalt from an unknown source, set in a sandy matrix	10

Unconformably underlain by shale of Sisquoc Formation

Age. The basal part of the fossiliferous sand and gravel 300 feet above the base of the "Pico" has yielded the following molluscan species as identified by W. L. Woodring (in Upson, 1951, p. 16):

Gastropoda
- *Calliostoma ligatum* (Gould) "*costatum Martyn*"
- *Turritella cooperi* Carpenter
- *Biffium* cf. *eschrichtii* (Middendorff)
- * *Crepidula princeps* Conrad
- *Crepidula* cf. *onyx* Sowerby
- *Neverita* cf. *reclusiana* (Deshayes)
- *Epitonium* cf. *tinctum* (Carpenter)
- *Odostoma* sp.
- *Mitra idae* Melvill
- *Neptunea* cf. *tabulata* (Baird)
- * *Calicantharus fortis* (Carpenter) var. cf. angulata (Arnold)
- *Tritonalia* cf. *foveolata* (Hinds)
- *Nucella* cf. *lamellosa* (Gmelin)
- *Mitrella carinata* (Hinds)
- *Mitrella carinata gausapata* (Gould)
- *Amphissa* cf. *versicolor* Dall
- *Olivella biplicata* (Sowerby)
- *Megasurcula carpinteriana* (Gabb)
- *Elaeocyma* cf. *empyrosia* (Dall)
- *Ophiodermella* cf. *ophioderma* (Dall)
- * "*Drillia*" cf. *graciosana* Arnold

*Species not known to be living. All others living or closely related to living species.

* "*Taranis*" cf. *iculta* (Moody)
  Conus californicus Hinds

Pelecypoda
  Glycymeris sp.
* *Pecten* cf. *hemphilli* Dall
  Chlamys cf. *hastatus* (Sowerby)
  Cyclocardia cf. *ventricosa* (Gould)
  Pachydesma cf. *crassatelloides* (Conrad)
  Saxidomus cf. *nuttalli* Conrad
  Pseudochama cf. *exogyra* (Conrad)

Of these species, *Pecten* cf. *hemphilli* occurs in the Careaga Sandstone of the Santa Maria district, and is closely related to *P. bellus* that occurs abundantly in the lower part of the Santa Barbara Formation. Several others of these species are found in that formation, and others occur in formations of Pliocene age. The "Pico" Formation of this exposure may be a fine sandy siltstone facies of the Santa Barbara Formation. However, the molluscan assemblage is considered by Woodring (in Upson, 1951, p. 16) to be of late Pliocene age and probably slightly older than that of the Santa Barbara Formation.

Santa Barbara Formation

Distribution and type locality. The term "Santa Barbara" was first used by Smith (1912, p. 169) and later by Carson (1925, pp. 265–270), and Grant and Gale (1931, p. 35). It was applied in the zonal time sense for marine sediments of latest Pliocene-early Pleistocene age in southern California, and named after exposures at Santa Barbara. The term is now generally applied to the marine formation of that age exposed in the hills southwest and west of the city of Santa Barbara. Other exposures of this formation occur in the low foothills north of Goleta Valley and east of Carpinteria Valley; it was penetrated by wells in both these valleys.

The type section of the Santa Barbara Formation is designated as that exposed on the east slope and top of Packard's Hill on the southwest side of the city of Santa Barbara. This section exposes about 140 feet of the lower part of the formation, and while this is a small section as compared to some subsurface sections in Goleta Valley which are several thousand feet thick, it is the only one that exposes both members of this formation, including the base, and is richly fossiliferous. Stratigraphically higher beds are exposed in the hills west from Packard's Hill.

Sandy sediments of the Santa Barbara Formation crop out as small isolated exposures in the foothills north of Goleta Valley. On Mescal Island and west across Goleta Slough is exposed a few feet of sand and basal conglomerate of either the Santa Barbara or the "Pico" Formation.

Topographic expression. The soft sands and silts of the Santa Barbara Formation erode to low rounded hills that support grasses, low brush, or oak timber. Exposures are poor except in sea cliffs, creek banks, or man-made cuts.

Thickness. The thickness of the Santa Barbara Formation is highly variable. A maximum exposed thickness of about 500 feet crops out in the hills west of Santa Barbara; but a well (Petroleum Exploration Co., McWilliams No. 1) drilled east of lower San Roque Canyon penetrated the formation to a depth of 2145 feet. The foothills northeast and north of Goleta Valley expose about 500 feet of the formation.

The greatest known thickness of the Santa Barbara Formation lies buried under Goleta Valley, where several test holes penetrated a maximum thickness of about 2200 feet just north of the More Ranch fault. An unknown thickness underlies the city of Santa Barbara. In Carpinteria Valley, several test holes near the town of Carpinteria, just north of the Carpinteria fault, penetrated several hundred feet of the Santa Barbara Formation after drilling through 3000 feet of the Casitas Formation.

Lithography and stratigraphy. The Santa Barbara Formation everywhere lies with angular discordance on formations ranging from Monterey to Sespe. The top of the formation is eroded in all surface sections, and in subsurface sections under the valley areas is buried by later formations.

The Santa Barbara Formation is composed of two parts, or members, that are lithologically and faunally distinct. The lower member is composed of fossiliferous fine silty and calcareous sediments of which *Pecten bellus* is the most distinctive fossil species, and is thin—probably not over 100 feet in thickness. This member is recognized at only a few places, such as at Packard's Hill and at Breakwater beach at the city of Santa Barbara.

The upper member makes up the major portion of the Santa Barbara Formation. It is 500 feet or more in thickness, and is composed of poorly consolidated, fossiliferous, buff to yellow, fine to coarse grained sands, in which *Pecten (Patinopecten) caurinus* is the most distinctive fossil. This member is exposed extensively in the "Mesa" hills west of Santa Barbara. It is also exposed in the low foothills north of Goleta Valley, and has been penetrated by numerous water wells in that valley.

The lower member of the Santa Barbara Formation is well exposed on a trail on the east slope of Packard's Hill. There it is about 90 feet thick and rests

*Species not known to be living. All others living or closely related to living species.

unconformably on the Sespe Formation. The member again crops out at Breakwater Beach, where about 60 feet is exposed, but the base is buried. At both places the member consists of soft to moderately indurated fossiliferous tan sandy silts, silty sands, and bryozoan gray marls. These beds are highly fossiliferous with numerous bryozoans, shell fragments, and tiny shells of many species of molluscs. The marl beds vary from 1 to 10 inches in thickness. Some are quite hard and protrude from the softer layers in which they occur, as in the small bluff just west of Banos del Mar swimming pools at Breakwater Beach. At this locality these beds of the lower member dip about 20° south, and are overlain, possibly unconformably, by about 10 feet of buff sands of the upper member that dip less steeply.

The type section of the Santa Barbara Formation exposed on the trail on the east side of Packard's Hill is as follows:

Santa Barbara Formation exposed on east and south sides of Packard's Hill, Santa Barbara.

	Estimated thickness (feet)
Sand, tan, very fine grained to silty, with occasional hard dark brown ferruginous layers as thick as one foot, no fossils, (exposed on south flank of hill)	60
Siltstone, tan, massive to poorly bedded, semifriable, sandy to clayey; some calcareous nodular layers, some layers of very fine sand; abundant molluscan shell fragments, including *Pecten hastatus* and *Pecten (Patinopecten) caurinus*, some bryozoans (exposed on crest of hill); probable base of upper Santa Barbara Formation	30
Siltstone, tan, bedded, soft, sandy to clayey, some layers as thick as one foot are hard, calcareous, nodular; abundant bryozoans, molluscan shell fragments, small gastropods, foraminifers	110
Sand, buff, massive, fine to medium grained, friable to hard, calcareous, nodular; abundant shell fragments	5
Siltstone, as last above	17
Sand, as above; abundant shell fragments and *Pecten bellus*	7
Shell coquina, white to tan, composed mainly of shell fragments and sand cemented to form a hard, calcareous stratum; base of lower Santa Barbara Formation	1
	230

Unconformably underlain by Sespe Formation (pink to buff sandstone and red siltstone).

The lower member has not been recognized elsewhere, except on top of a hill east of San Roque Canyon and south of the Lavigia fault, where a nearby flat-lying erosional remnant of bryozoan marls and sands containing *Pecten bellus* lies unconformably on steeply dipping Rincon claystone and Monterey Shale. This member may occur at depth under Goleta Valley, but its presence has not been definitely ascertained in any wells.

The upper member of the Santa Barbara Formation is generally flat-lying and is composed almost entirely of buff to yellow, fine- to medium-grained massive to bedded sands. They generally contain scattered molluscan fossils or shell fragments, but locally are barren of fossils. The sands contain coarse layers locally, and in a few places contain rounded pebbles of hard durable rock types such as quartzite, porphyry, and black chert. The weakly consolidated sands of this member are prominently exposed in large cuts at the west end of Valerio Street, Santa Barbara, and also in a quarry a quarter of a mile east of Veronica Springs in lower San Roque Canyon.

The soft, bedded sands of the upper member are locally hardened by calcareous cement. Near Veronica Springs in lower San Roque Canyon these sands are locally extremely hard. At Punta del Castillo at Breakwater Beach some of the sands of the upper member are likewise hardened. At this point there once existed a famous landmark, known as Castle Rock, removed in 1931, that was composed of calcified, flat-lying bedded sandstone of this member. This calcified sandstone does not appear to be confined to any one horizon in the Santa Barbara Formation, but is probably the result of local impregnation of the soft sands by carbonate-bearing waters that may have worked in along faults and deposited calcium carbonate in the soft porous sands, thus hardening them.

The Santa Barbara Formation encountered in wells drilled for water and oil in Goleta Valley, and in water wells in the city of Santa Barbara, is composed of fossiliferous buff sands.

In Carpinteria Valley the Santa Barbara Formation is not exposed, but crops out to the east in the lower part of Rincon Creek. In this exposure it lies unconformably or in fault contact with the Rincon Shale to the south and dips northward under red beds of the conformably overlying Casitas Formation; it is composed of fine yellow fossiliferous sands and brown clays, with abundant *Turritella cooperi*. The stratigraphic sequence of the Santa Barbara Formation of this section, with a measured thickness of 596 feet, is described in detail by Upson (1951, p. 20).

Conditions of deposition. Deposition of the "Pico" and Santa Barbara Formations was preceded by an interval of major uplift and erosion of the entire coastal area, as indicated by the major unconformity at their bases. This major disturbance was probably contemporaneous with that which affected the Santa Ynez River area prior to deposition of the Careaga Sandstone. These were no doubt the local effects of the great emergence, after deposition of the Sisquoc Formation, of the Santa Ynez and San Rafael Mountain areas, which underwent uplift, deformation, and erosion throughout late Pliocene and Pleistocene times.

The sandy sediments of the "Pico" and Santa Barbara Formations accumulated under waters of a very

shallow sea that transgressed northward over the eroded surface of the coastal plain on the southern margin of the Santa Ynez Mountain uplift. It is doubtful if the Santa Barbara Formation was ever deposited much beyond its present northern limits, which probably mark the location of the ancient shore line of the sea under which it accumulated. This shore line must have passed from the vicinity of Elwood oil field eastward along the northern foothills of Goleta Valley, the southern base of Mission Ridge, and thence eastward through the town of Summerland, and along the northern edge of Carpinteria Valley.

The 2000-foot thickness of the Santa Barbara Formation under Goleta Valley indicates the coastal area subsided that much during deposition of this formation.

The consistently sandy texture of the Santa Barbara Formation and its molluscan fauna indicate this formation was deposited in very shallow water, probably on a shallow marine shelf. The water was probably only a few fathoms deep. Some of the upper sands may have been deposited very close to sea level, or even slightly above it, in places.

The *Pecten bellus* fauna of the lower part of the Santa Barbara Formation indicates cold temperature, as most of the species of this fauna are now living at a latitude with a midpoint range of 39.0° N. latitude. The *Pecten caurinus* fauna of the upper part of the Santa Barbara Formation indicates a temperature even colder, as most of its species are now living at a latitude even farther north, with a mid-point range of 43.0° N. latitude (A. Myra Keen, written communication, Feb. 6, 1942). This cold temperature was probably the local effect of the early ice age of the Pleistocene epoch.

Age and Correlation. The lower member of the Santa Barbara Formation carries a large molluscan assemblage of the *Pecten bellus* fauna. This is generally assigned to the uppermost part of the Pliocene epoch, but may belong to the lowermost Pleistocene.

The upper member of the Santa Barbara Formation contains many molluscan species of the *Pecten (Patinopecten) caurinus* fauna. This is generally assigned to the early Pleistocene.

Species from Santa Barbara Formation of Parkard's Hill, from trail on east slope of hill, southeast of TV station. Identified by A. Myra Keen.

* *Pecten bellus* Conrad
† *Pecten (Patinopecten) caurinus* Gould
* *Pecten (Chlamys) opuntia* Dall
Pecten (Chlamys) hastatus Sowerby
Pecten (Chlamys) jordani Arnold
† *Pecten (Chlamys) hindsii* Carpenter
† *Pecten (Propeamusium) viversi* Arnold
* *Cardita monilicosta* Gabb
Cardita ventricosa Gould
* *Pseudochama exogyra* Conrad
* *Pseudochama granti* Strong
* *Trachycardium quadragenarium* (Conrad)
Lucina annulata (Reeve)
† *Macoma* cf. *nasuta* (Conrad)
† *Macoma* cf. *Carlottensis* Witeaves
* *Panope generosa* Gould
* *Epilucina californica* (Conrad)
Turritella cooperi Carpenter
* *Crepidula princeps* Conrad
* *Mitrella carinata* (Hinds)
* *Moniliopsis graciosa* (Arnold)
* *Nassarius fossatus* (Gould)
* *Nassarius mendicus* (Gould)
Neptunea tabulata (Baird)
Olivella biplicata (Sowerby)
Homilaria perlaminosa (Conrad)
† *Psephidia barbarensis* (Arnold)
† *Compsomyax subdiaphana* (Carpenter)
Acteocina calcitella (Gould)
Antiplanes perversa (Gabb)
† *Bittium asperum* (Gabb)
† *Bittium catalinense* Bartsch in Arnold
† *Solariella permabilis* (Carpenter)
† *Tegula* cf. *pulligo* (Gmelin)
Zizyphinus virgineus (Dillwun)
† *Lacuna carinata* Gould
† *Albina effia* Willett
† *Amphissa columbiana* Dall
† *Exiliordea rectirostris* (Carpenter)
† *Natica aleutica* Dall
† *Glyphostoma conradiance* (Gabb)
† *Tortonalia barbarensis* (Gabb)

Species from Santa Barbara Formation, bryozoan marls of lower member, from bluff at Breakwater beach, Santa Barbara. Identified by L. G. Hertlein.

Culingia californica Conrad
Cryptomya californica Conrad
Protothaca staminca Conrad
Schizothaerus nuttalli Conrad
Amphissa versicolor Dall
Bittium eschrichtii Middendorff
Calliostoma annulatum Martyn
Conus californicus Hinds
Olivella biplicata Sowerby
Crepidula adunca Sowerby
Nassaria mendica Gould
Nassaria mendica cooperi Forbes
Mitra idae Melvill
Diodra aspera Eschscholtz

Turritella cooperi, *Olivella biplicata*, and *Pecten hastatus* occur abundantly in both members of the Santa Barbara Formation in the hills west of Santa Barbara, and in the beds exposed in the vicinity of the Santa Barbara County Hospital northwest of Santa Barbara. *Pecten (Patinopecten) caurinus* is locally abundant in the latter beds and in those exposed north of Goleta Valley, as well as in the upper beds in the hills west of Santa Barbara.

The Santa Barbara Formation is lithologically similar to the Careaga Sandstone north of the Santa Ynez Range, but the fauna of the Santa Barbara beds indicates it to be slightly younger (W. L. Woodring, oral communication, 1948), and probably correlative with the Paso Robles Formation.

* Species from lower member only.
† Species from upper member only.
All others from both members.

Casitas Formation

Type locality and distribution. The Casitas Formation is a series of stream-laid gravels, sands, and clays that overlies the Santa Barbara and older formations in Carpinteria Valley and is overlain by fanglomerate and older alluvium. The Casitas Formation was named and described by Upson (1951, pp. 21–23) for typical and most complete exposures at Rincon Creek near its juncture with Casitas Creek, Ventura quadrangle, 3 miles east of Carpinteria. From the vicinity of Rincon Creek the Casitas Formation extends west for several miles along the foothills north of Carpinteria Valley. Other exposures occur on the coast both east and west of Summerland, and in a low sea cliff southwest of Montecito.

In lower Rincon Canyon just east of the map area the Casitas Formation consists of two parts. The lower part, about 1000 or more feet in thickness, but with only about 188 feet exposed, is predominantly red to greenish clay, silt and sand in fairly regular beds; it rests conformably on marine sand and clay of the Santa Barbara Formation. The upper part, several hundred feet in thickness but with only about 400 feet exposed, is crudely bedded fanglomerate, cobble gravel, and pebble silty sand. Most of the fragments are of Eocene sandstone, but many are of quartzite, chert, and jasper, probably reworked from conglomerates of the Sespe Formation. The upper part laps northward over the lower part of the Casitas Formation onto the Sespe Formation exposed to the north.

Carpinteria Valley is underlain by a great thickness of the Casitas Formation, as two test holes drilled for oil near the town of Carpinteria just north of the Carpinteria fault penetrated soft reddish sands and clays of this formation to depths as low as 3200 feet, then passed into marine sands of the underlying Santa Barbara Formation. From this part of the Valley the Casitas Formation must thin rapidly northward, probably by successive loss of lower beds, as at Rincon Canyon; for a test hole drilled near Cate School, 2 miles northeast of Carpinteria, penetrated the Casitas Formation to a depth of 1000 feet, then entered the Sespe Formation. In the foothills north of this valley, only a few hundred feet of the coarse uppermost beds of the Casitas crop out, and these rest unconformably on the Sespe Formation.

At Summerland the upper part of the Casitas Formation is well exposed on the sea cliff and highway cut just west of the town, where the beds dip southwest. The section is composed of about 400 feet of buff fanglomerate, gravel, and silty sand like that exposed at Rincon Creek and in the foothills north of Carpinteria Valley. These coarse, ill-sorted sediments grade downward into the lower part of the Casitas Formation, which is composed of about 200 feet of gray faintly bedded sand and silt and some pebbly layers. Similar gray sands and silts are exposed in the sea cliff half a mile southeast of Summerland. These lower beds thin out rapidly northward on shore.

In the now-abandoned Summerland oil field the numerous wells penetrated a maximum thickness of 550 feet of sands and clays that are probably of the Casitas Formation or possibly of the Santa Barbara Formation. These beds were described as the "Fernando Formation" by Arnold (1907, pp. 30–33), but he reported no fossils from them. Cross-sections through this field by Arnold (1907, pls. 6, 7, 8) show a general southward thickening of these beds. Where the sequence is thickest, it is composed of about 200 feet of gravel, sand, and some clay; underlain by about 200 feet of "blue clay," sand, oil sand, and some gravel; in turn underlain by 150 feet of gypsiferous clay that rests unconformably on Miocene shale.

On the low sea cliff southwest of Montecito is exposed about 100 feet of buff to brownish gray pebbly sandstone and cobble gravel that may be the uppermost part of the Casitas formation, as was believed by Upson (1951, pl. 1). An unknown thickness of this formation must underlie the coastal plain under Montecito and under the eastern part, if not all of, the city of Santa Barbara. The Casitas Formation is not known to underlie Goleta Valley to the west, but part of the poorly exposed unfossiliferous sand mapped as the Santa Barbara Formation in the foothills to the north within a mile west of San Jose Creek may be the nonmarine Casitas facies.

Conditions of deposition. The Casitas Formation is composed of detritus derived from the rising Santa Ynez Mountains to the north. This detritus was washed down by streams and deposited as deltaic sediments that built out as a coastal plain in the Carpinteria sector into the shallow sea in which the Santa Barbara Formation was accumulating. The sands and clays of the lower part of the Casitas Formation were deposited by relatively quiet streams and were probably derived mainly from the Sespe Formation, as is suggested by their reddish color and pebbles derived from Sespe conglomerates. The coarse sediments of the upper part of the Casitas Formation were deposited by torrential streams as alluvial fanglomerates and sandy gravels and were derived mainly from the Eocene sandstones of the Santa Ynez Mountains which must have been quite high and rugged by that time.

The great thickness of the Santa Barbara-Casitas sedimentary sequence that accumulated on the site of the present coastal plain indicates this area subsided

several thousand feet, while the adjacent Santa Ynez Range was elevated and eroded. This would result in a strong southward tilt of the area. These sediments must have accumulated south of the range contemporaneously with the Careaga-Paso Robles sequence north of it, during which time both the Santa Ynez and San Rafael ranges were continuously elevated and eroded.

Age and correlation. The Casitas Formation is in part younger than the Santa Barbara Formation which it conformably overlies, under and east of Carpinteria Valley; and is in part equivalent to at least the upper part of that formation. It is thereby of early Pleistocene age, the age of the equivalent Santa Barbara Formation. The upper part may be of middle or even late Pleistocene age, as under Carpinteria Valley it may be conformably overlain by alluvial sediments equivalent to the Pleistocene sediments mapped as older alluvium and fanglomerate.

The Casitas Formation is no doubt correlative with much of the Paso Robles Formation north of the Santa Ynez Range, to which it is similar, as both were deposited under similar conditions. It is probably also equivalent to the similar-appearing non-marine Saugus Formation exposed in the foothills in the vicinity of Ventura, as mapped by Putnam (1942, p. 1).

Paso Robles Formation

Type locality. The Paso Robles Formation is a series of terrestrial clays, sands, and conglomerates that conformably overlies marine sands of upper Pliocene age in Salinas Valley and was first described by Fairbanks (1898, pp. 565–566) for exposures around the town of Paso Robles. A similar formation, referred to the Paso Robles Formation by Nelson (1925, pp. 374–376), Woodring, and Bramlette (1951, pp. 49–51) and the writer (Dibblee, 1950, p. 47), underlies much of the lowland area between the San Rafael and Santa Ynez Mountains.

Distribution. The Paso Robles Formation is almost entirely confined to the lowland area north of the Santa Ynez River and west of Loma Alta and lower Redrock Canyon. South of the Santa Ynez River across from the mouth of Santa Cruz Creek is a small exposure of what appears to be the basal part of the Paso Robles Formation.

Topographic expression. As the Paso Robles Formation is generally weakly consolidated, in most places it erodes to low hills with gentle slopes, and supports grasses or low brush. However, in some places north of the river, conglomerates in the upper part of the formation are sufficiently consolidated to form prominent bluffs.

Thickness and stratigraphic relations. The Paso Robles Formation exposed just north of the Santa Ynez River is about 2500 feet thick. The formation lies conformably on the Carega Sandstone and the top is a surface of deposition that forms the elevated part of the Santa Cruz Valley west of Cachuma Canyon. Farther east this surface and the upper beds have been eroded away.

Lithology and stratigraphy. The Paso Robles Formation is composed of interbedded weakly consolidated conglomerates, sandstones, and clays. There is no definite sequence of beds, but generally finer sediments predominate in the lower half of the formation, and coarser ones in the upper half.

The clays range in color from greenish-gray to light reddish-brown and are argillaceous to silty, commonly gritty or even pebbly. They are composed of finely comminuted Monterey Shale and soil material. They grade into light gray sandstones composed of grains of quartz, of Monterey cherty shale and of Franciscan chert. Both the clays and sandstones grade into light colored conglomerates with the addition of rounded pebbles that are composed almost entirely of Monterey white siliceous shale. The pebbles average less than an inch in longest dimension, but some layers contain cobbles as much as 7 or 8 inches in longest dimension. Pebbles of Eocene and Cretaceous sandstone appear in some places, especially in the vicinity of Horse Canyon. In other places, especially near the top of the formation, in the area west of Cachuma Canyon, are pebbles and cobbles of Franciscan chert, greenstone, sandstone, and serpentine. Many of the conglomerates are cross-bedded.

The basal part of the questionable Paso Robles Formation exposed in a syncline south of the Santa Ynez River west of San Marcos Ranch is composed of about 100 feet of greenish to light reddish clay, sand, and some conglomerate with sandstone cobbles. These beds, which may be part of a later terrace deposit, lie on both the Careaga Sandstone and on Sisquoc diatomite.

Conditions of deposition. The Paso Robles Formation was deposited in a nearly level valley area between the San Rafael and Santa Ynez Ranges, both of which probably rose continuously during Paso Robles time. The Paso Robles sediments were derived from both these rising mountains, which at that time were largely exposures of Monterey Shale, as indicated by the predominance of this material in the sediments. The sediments were deposited by streams in the intervening valley area which continued to subside as it filled, until a thickness of at least 2500 feet of these sediments accumulated in it. The increasing coarseness of the

Photo 19. Exposure of Pleistocene fanglomerate of sandstone detritus. San Marcos road east of San Antonio Creek.

formation from bottom to top indicates that the adjacent mountains were becoming increasingly rugged.

Age and correlation. The Paso Robles Formation is unfossiliferous, so its age is not definitely known. However, it is younger than the upper Pliocene Careaga Sandstone which it overlies. The surface of deposition at the top is probably of Pleistocene age, as in much of the Santa Ynez Valley area it is undeformed and undissected. It may be concluded that most, if not all the Paso Robles Formation is probably of Pleistocene age, but there is a possibility that the lower part may be of late Pliocene age.

The Paso Robles Formation is probably the same age as the Paso Robles Formation of Salinas Valley, and the Santa Barbara and Casitas Formations of the coastal area.

Fanglomerate

Distribution and general features. The oldest fanglomerate, or that which covers upper Santa Ynez Valley west of lower Cachuma Canyon, is an old valley fill about 200 feet thick that lies with slight angular discordance on the Paso Robles Formation in Los Alamos syncline. The fanglomerate of this fill is composed of cobbles and pebbles derived from conglomerates of the Paso Robles Formation and from all older formations on both sides of this valley. It is practically undissected in this valley area, but to the south, where it laps onto the eroded surface of the Paso Robles and older formations, it is dissected into remnants that cap the ridges. The fanglomerate of these remnants is tilted gently northward and is apparently involved in the latest folding of Los Alamos syncline.

Elsewhere in the map area coarse fanglomerate constitutes old alluvial fans at both the northern and southern bases of the Santa Ynez Range; this fanglomerate lies on the eroded surface of tilted and deformed Tertiary and lower Quaternary formations. In these alluvial fans the fanglomerate is several hundred feet in maximum thickness, in places as much as 300 feet. It is brownish-buff in color and is composed of unsorted boulders, cobbles, and pebbles of sandstone, and pebbles of shale, derived from the Eocene formations of the Santa Ynez Range. The clasts are embedded in a comminuted sandy matrix of the same detritus. Some of the sandstone boulders are as much as 7 feet in longest dimension. Adjacent to the mountains near the Santa Ynez fault the fanglomerate is practically landslide material with no semblance of bedding; but downslope away from the mountains it gradually becomes less coarse, somewhat sorted, and crudely bedded. In places, the sandstone boulders of the fanglomerate are weathered friable like its sandy matrix, so that it takes on the general appearance of a sandstone.

On the north side of the range the largest fans are below Hilton and Tequepis Canyons; several smaller ones are farther east. The heads of these fans fill their respective canyons as they emerge from the mountains, and fan out down slope over more ground. These fans are undeformed, but all are dissected as they are now several hundred feet above the present base level of the Santa Ynez River and its tributaries.

On the south side of the Santa Ynez Range, fanglomerate occurs as dissected piedmont alluvial fans from the foothills north of Goleta eastward to those northeast of Montecito. All these fans are slightly elevated, possibly by southward tilt, and dissected. Some are even disrupted by faulting, such as the one northeast of Goleta Valley and the one north of the city of Santa Barbara. The latter is also elevated and deformed on the south side of the Mission Ridge fault. These fans are probably not all contemporaneous, as those in Montecito Valley are at lower levels than those north of Santa Barbara, but it is not certain how much of the difference in level is the result of tectonic disturbances since deposition of the fanglomerate. At any rate, the surface of deposition of these old piedmont fans blends southward down slope into that of the older and younger alluvium of the valley areas. In the headward portions of these fans, the fanglomerate is composed of very coarse detritus derived from the Eocene sandstone of the adjacent mountains. In the downslope portions in the low hills between Goleta Valley and the city of Santa Barbara, the fanglomerate is composed of ill-sorted cobble gravel and coarse to fine sand that are in places maroon

red and appear to have been derived in part from the Sespe Formation.

Conditions of deposition. The coarse fanglomerate was deposited as large alluvial fans at the base of the Santa Ynez Range by torrential downpours that must have been more severe than anything known today in this region. These must have occurred during the Pleistocene ice ages, causing severe erosion in the mountains. Outwash from these piedmont fans probably filled the valley areas and was in part deposited as older alluvium. The fanglomerate and older alluvium were deposited after a period of emergence and erosion in mid-Pleistocene time, after deposition of the early Pleistocene Paso Robles, Santa Barbara, and Casitas Formations.

Probable age. The fanglomerate has not yielded any fossils within the map area. However, it is younger than the early Pleistocene Casitas and Paso Robles Formations which it overlies unconformably, but older than the undissected Recent alluvium and some of the dissected older alluvium. This would indicate a middle or late Pleistocene age.

Older Alluvium

Distribution and character. All elevated and dissected Quaternary alluvial gravel, sand, and silt, exclusive of coarse fanglomerate, are mapped as older alluvium. North of the Santa Ynez Range they form terrace deposits at several levels on either side of the Santa Ynez River and its tributaries. All these terrace deposits are at lower levels than the old alluvial fans of fanglomerate, and are therefore all younger. They were deposited on the former flood plain of the Santa Ynez River and its tributaries when the region was slightly lower than it is now. They are not deformed, but have been dissected into terrace remnants since the region was slightly elevated and the Santa Ynez River and its tributaries deepened their channels. The older alluvium of these terrace deposits is as much as 90 feet in thickness, and consists of unconsolidated stream laid gravel, sand, and silt.

On the coastal plain south of the Santa Ynez Range a mantle of older alluvium, as much as several hundred feet in thickness, composed of gray to buff poorly sorted and crudely bedded gravel, sand, and silt, underlies the valley areas. In the level parts of these areas it is largely buried by younger alluvium; but on the margins, especially in the northwestern part of Goleta Valley, it is slightly elevated and dissected. The older alluvium of these valley areas may be in part equivalent to the fanglomerate of the old dissected alluvial fans, or to the youngest of these fans, into which it may grade to the north. In mapping, it was separated from the coarse fanglomerate because it is composed of finer sediments.

Adjacent to the coast the older alluvium forms a thin mantle 30 to 60 feet thick on the beveled surface of deformed Miocene and Pliocene formations. Its top is from 50 to 150 feet above sea level. The mantle of older alluvium covers the low coastal mesa south of Goleta Valley, and erosional remnants of it cover the coastal terrace westward to and beyond the western border of the map area, and eastward to Breakwater Beach. The older alluvium of this mantle is composed of a basal layer of pebble and cobble gravel, overlain by eolian sand with some silt and clay. Along the coastal bluffs the basal layer is composed of several feet of marine pebbly sand with abundant molluscan shells, mostly large Pholads, many of which have bored several inches or feet into the underlying Tertiary bedrock. In the adjacent Gaviota quadrangle, the coastal terrace deposits, as well as the wave cut terraces at higher levels, are described in detail by Upson (1951, pp. 421–438).

The area adjacent to the sea cliffs at Summerland and the low coastal mesa southeast of Carpinteria are likewise covered by a thin mantle of older alluvium. This deposit is exactly similar to that of the coastal areas westward from Santa Barbara, and occurs at about the same elevation.

The older alluvium is probably late Pleistocene. It has yielded mammalian fossils at two localities. One of these from sec. 7, T. 4 N., R. 27 W., near Goleta, was a fragment of a mastadon jaw identified by Phil. C. Orr of the Santa Barbara Museum as *Mastodon americanum*. The other fossil, from a railroad cut 11 miles west of Goleta, is a jaw bone of a mammoth identified by him as *Archidiscodon imperator*. He considers both of these to have lived in late Pleistocene time. They must have lived under cold climatic conditions.

East of Santa Barbara the older alluvium has yielded numerous fossils at the tar pits a mile southeast of Carpinteria. These include not only marine molluscan fossils, but remains of birds and mammals that got mired in the tar springs, and also remains of numerous plants. These fossils are described in detail in a series of articles—Grant and Strong (1934, pp. 1–5) describe the marine invertebrates; Miller (1931, pp. 361–374) the vulturine birds; Miller (1932, pp. 169–194) the passerine birds; Chaney and Mason (1933, pp. 45–79) the plants; and Wilson (1934, pp. 59–76) the land vertebrates. The consensus of these articles is that almost all species of these animals that lived in this area in late Pleistocene time are still living, but in an environment of climate that is cooler and more humid than the present climate of this district—that is, more like that of the Monterey Peninsula area.

Alluvium

Undissected alluvium of Recent age underlies the present flood-plain of the Santa Ynez River and those of its main tributaries. The alluvium that fills these flood plains consists of a few feet or tens of feet of unconsolidated gravel, sand, and silt derived from the drainage areas of the respective streams.

On the coastal plain, undissected Recent alluvium fills the lower levels of all the valley areas; the small flood-plain valleys of the major streams that drain into them; and flood plain valleys of the major streams that drain directly into the sea. In the flood-plain valleys the alluvium consists of basal gravel overlain by gray, tan to reddish sand and silt derived from the drainage area of the respective streams, lying unconformably on formations ranging from lower Pleistocene to Eocene. In the broad valley areas it consists of gray, tan to light reddish clay, silt and sand, and local bodies of gravel at the base. In these valley areas north of the More Ranch, Mesa, and Carpinteria faults, the alluvium rests on either older alluvium, or the Casitas or Santa Barabara Formations. In Goleta Valley, water wells pass from alluvium into fossiliferous sands of the Santa Barbara Formation. In Carpinteria Valley, water wells pass from alluvium into nonmarine sediments of either the older alluvium or Casitas Formation that are difficult to distinguish from the alluvium in the well logs.

The thickness of the undissected alluvium of the coastal plain ranges from a feather edge to more than 200 feet, as idicated in water-well logs. In Goleta Valley this alluvium is as much as 225 feet thick, according to Upson (1951, p. 25). It may be even thicker in Carpinteria Valley. While the Recent alluvium of the coastal plain was deposited by streams on land, it is noteworthy that in all the broad valleys, and all flood plain valleys of the major streams that drain into the sea, it extends to depths below sea level, and even extends out under the sea beyond these valleys for unknown distances. In Goleta Valley, the alluvium extends to depths as much as 200 feet below sea level. Several test holes drilled for oil on the sand spit across the outlet of this valley penetrated alluvium to 225 feet below sea level, then entered the Monterey shale (Upson, 1949, p. 104). Under the city of Santa Barbara at and near the beach and under Carpinteria Valley the alluvium probably extends to similar depths below sea level. This condition is ascribed by Upson (1949, p. 111) to a 200- or possibly 300-foot rise of sea level since beginning of deposition of the alluvium, or since the last (Wisconsin) glacial stage.

STRUCTURE

Tectonic Blocks

The structural setting of the mapped district is as shown in the accompanying simplified geologic map of the Santa Barbara-Ventura County region, figure 9. The geologic structure within the district is shown on the geologic map and the tectonic map (fig. 4).

The district includes parts of three major tectonic blocks, namely, 1) Santa Ynez Mountain block; 2) San Marcos block; and 3) Little Pine Mountain block.

The Santa Ynez Mountain block occupies the southern and major part of the district. This block is bounded on the north by the Santa Ynez fault, along which the block was elevated and tilted southward. The Santa Ynez Range is the elevated northern part of the block, and the adjacent coastal plain is the relatively downtilted southern part. Only the central 29-mile sector of this mountain and coastal block lies within the map area; the western sector extends to Point Arguello and was mapped by the writer (Dibblee, 1950); the eastern sector in Ventura County was mapped by Putnam (1942). This block is really the northern flank of the huge trough-like Ventura sedimentary basin, of which the sunken part is submerged under the Santa Barbara Channel.

The northwestern part of the district includes the southeastern part of a sector of the Santa Ynez lowland wedge referred to as the "San Marcos block" by Nelson (1925, p. 387). This block is essentially a synclinal trough and is bounded on the south and northeast respectively by the Santa Ynez and Little Pine faults. This block is part of a much larger lowland wedge between the Santa Ynez and San Rafael Mountains, which extends to the west coast of Santa Barbara County. This lowland wedge, which includes the Santa Ynez, Lompoc, Los Alamos, and Santa Maria Valleys and intervening hills, is a large sedimentary basin of formations ranging in age from Miocene to Plio-Pleistocene. Over most of this basin these formations rest unconformably on Franciscan or Lower Cretaceous rocks, and are moderately compressed into broad open folds with axes trending generally west-northwest. Parts of this large sedimentary basin were mapped and described by Arnold and Anderson (1922), Nelson (1925), Woodring and Bramlette (1951), and the writer (1950).

The northeastern part of the district includes part of a tectonic block within the San Rafael Mountains that was referred to as the "Little Pine Mountain block" by Nelson (1925, p. 382). This block is bounded on the southwest by the Little Pine fault along which it was elevated, on the south by the

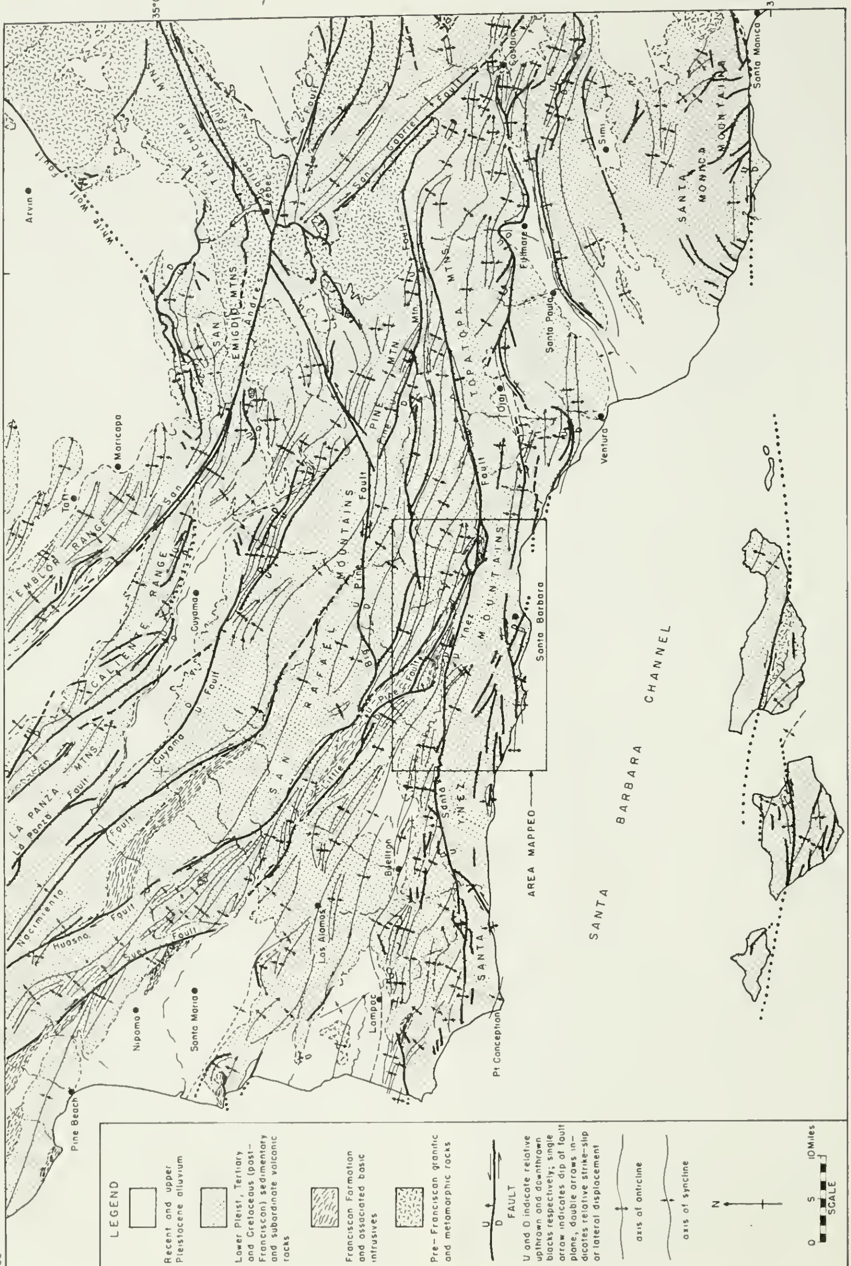


Figure 9. Map of Santa Barbara region showing major faults, axes of major folds, and structural setting of the central Santa Ynez Mountains.

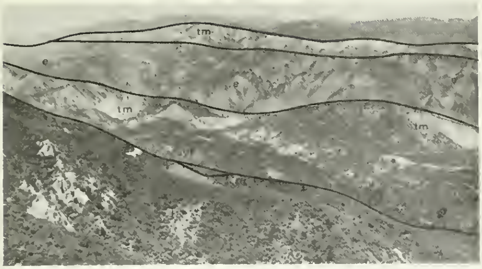


Photo 20. View northwest from Santa Ynez range. Gibraltor Dom at right. Shows following formations: Juncal Formation (j) in foregraund; trace of Santa Ynez foult (syf); trace of Little Pine fault (lpf); "Temblor" and Monterey formations (tm) in Santa Ynez River Canyon; Espada Formation (e) on Camuesa Ridge; "Temblor" and Monterey formations (tm) on Little Pine Mountain Ridge in distance.

Juncal Camp fault and eastern part of the Santa Ynez fault, and on the north by the Hildreth and Munson Creek faults. The block includes Little Pine Mountain, Camuesa Ridge, and the low mountains and hills to the east. Within the district there is actually no eastern limit to this block, as it merges with the mountain area to and beyond the eastern border of the district. Parts of this mountain block were mapped by Kew (1919), Nelson (1925), Walker (1950) and Page, Marks and Walker (1951).

Santa Ynez Mountain Block

General Structure

The structure of the Santa Ynez Range south of the Santa Ynez fault is homoclinal with a regional southerly dip toward the Santa Barbara Channel. The elevated mountain block that forms this range is composed of a thick series of Upper Cretaceous, Eocene, and Oligocene rocks, of which the Cretaceous rocks crops out on the north slope, the Eocene rocks on the crestal portion and south slopes, and the Oligocene rocks on the southern foothills.

The structure of the Santa Ynez Range within the district is generally regarded as being anticlinal (Arnold, 1907; Hill, 1932, p. 537, fig. 4; Upson, 1951, p. 26). This view, however, is only partly true. If the north-dipping structure of the foothills north of the Santa Ynez fault is included, the structure of this range, broadly speaking, may be regarded as a faulted anticline; if not, then the structure is homoclinal. However, the range is in part anticlinal for a few miles west of San Marcos Pass, but this anticlinal structure cancels out with a syncline to the northeast, as described in a following paragraph, so that it is only a local fold within the south-dipping homoclinal structure of the mountain block.

Folds

Homocline of western sector. The western sector of the Santa Ynez Mountain block is the eastern extension of the southern structural block of these mountains described earlier (Dibblee, 1950, p. 53) as a south-dipping homocline in Cretaceous and Eocene formations elevated on the Santa Ynez fault. In the vicinity of Santa Ynez Peak the strata strike east parallel to the crest of the range and dip south at low angles on the north flank, and at about 45° on the south flank.

Folds of San Marcos Pass area. Eastward the Eocene strata become arched into the large Brush Peak anticline, whose axis trends south of east and plunges southeast at an average angle of about 10°.

At San Marcos Pass the Brush Peak anticline cancels with a complimentary syncline to the northeast that is prominently exposed in Laurel Canyon after which it is named, and is mainly within the "Coldwater" Sandstone at the surface. The axis of this syncline is parallel to that of the Brush Peak anticline and plunges very gently southeast.

The Laurel Canyon syncline is flanked on the northeast by a moderately compressed anticline, largely in the "Coldwater" Sandstone, with an axis trending northwest and plunging gently southeast. This fold cancels with another syncline to the northeast, referred to as the Painted Cave syncline, that contains an infolded remnant of the Sespe Formation, plunges northwest and becomes tightly compressed as it approaches the Santa Ynez fault.

The Laurel Canyon and Painted Cave synclines and intervening anticline together form a structural saddle in the Santa Ynez Range between the Brush Peak anticlinal arch to the southwest and the southwest-dipping homoclinal structure to the east. To the northwest the axes of the above described folds tend to swing parallel to the Santa Ynez fault as they approach it, suggesting left-lateral drag movement on the fault; they are eventually terminated by it.

Homocline of eastern sector. East of the Painted Cave syncline the Eocene and Cretaceous strata all strike diagonally northwest into the Santa Ynez fault and dip southwest about 30°. Eastward they gradually strike east, parallel to the Santa Ynez fault and the crest of the range, and dip south at increasingly high angles. Farther east they become vertical, and for at least 9 miles along strike between Cold Spring Canyon and the east border of the map area, they are overturned southward. Adjacent to this overturn on the north is a 4-mile-long sliver of highly brecciated and sheared Franciscan rocks that appears to have been squeezed up as a plastic mass along the Santa Ynez fault. This overturn is probably the result of outward

push by this plastic mass against the upturned strata south of it, as will be discussed more fully in a following paragraph.

Santa Ynez Fault System

Areal extent. The Santa Ynez fault, along which the Santa Ynez Range was elevated, is the largest fault within the district. Part of it was mapped and described by Kew (1919, p. 20); another part, farther east, was mapped by Page, Marks and Walker (1951, pp. 1768–1773). The part west of the district was mapped and described by the writer (Dibblee, 1950, pp. 54–56).

The Santa Ynez fault and associated subsidiary faults constitute a major active fault system. From Gaviota Pass the Santa Ynez fault has been traced by the writer continuously eastward along the northern base of the Santa Ynez and Topatopa Ranges for more than 65 miles into Sespe Canyon, Ventura County. Along its entire 80-mile course the southern block is elevated to form the mountain block, and the maximum throw amounts to several miles.

Topographic expression. Along most of its course through the district, the Santa Ynez fault is well expressed topographically as it marks the base of the steep north-facing escarpment of the Santa Ynez Range. Only in the area north of San Marcos Pass does it fail to appear topographically; in that area it is concealed under Quaternary alluvium.

Eastward from Lewis Canyon, where the fault follows a generally straight course, it is marked by an alignment of notches across ridges at the base of the steep north slope of the range. In many places the fault is followed for short distances by stream channels that drain this slope. Nearly all of them follow the fault in a westerly direction, then resume their northward course to the Santa Ynez river. The longest of these is Blue Canyon, which follows the fault for 3 miles; another, southeast of Juncal Dam, follows the fault for 2 miles. Several minor northward-flowing stream channels are jogged westward along this part of the fault for a few hundred feet. Some of these are described in detail by Page, Marks, and Walker (1951, p. 1768). The westerly deflection by the fault of stream channels that drain northward across it is strongly suggestive of a left lateral component of displacement on this part of the fault, along which the elevated southern block is being displaced eastward relative to the northern block.

The Santa Ynez fault itself is rarely exposed, as it is either covered by black residual soil that supports dense brush, or, more commonly, is concealed by landslide debris from the mountain slopes to the south. Where seen, the fault is marked by slickensided black clay gouge that commonly contains thin lenses of white crystalline calcite as much as an inch or two in thickness. The gouge zone is usually several tens of feet wide. South of this gouge zone is a zone of sheared and crushed rock as much as 1,000 feet wide.

Fault relationships and dip. In Hilton Canyon and beyond the western border of the district, the Santa Ynez fault zone is composed of two closely spaced faults (Dibblee, 1950, p. 54). Both have large displacements, and the southern fault appears to be the more recently active. The northern fault follows a straight course, is vertical, and brings a block exposing steeply dipping Sespe, Vaqueros, and Rincon Formations on the south against the block to the north that exposes the Espada Shale, overlain unconformably by Eocene rocks, which in turn are overlain unconformably by the Monterey Shale. This anomaly is either the result of reversal of vertical displacements during Cenozoic time, or what is more likely, several miles of left lateral displacement in late Cenozoic time. East of Hilton Canyon this vertical fault passes under the southward-dipping southern fault, which is apparently younger, and does not reappear to the east.

The southern fault has a sinuous surface trace in Wons and Hilton Canyons, and dips southward, at low angles, in places as low as 10°. Along this fault the southern or mountain block exposing Upper Cretaceous and Eocene formations is elevated and thrust northward over the narrow block between this fault and the northern fault; eastward from Hilton Canyon it is thrust onto the San Marcos block just beyond the northern fault. A test well for oil, drilled by the Ohio Oil Company in Hilton Canyon, spudded in the Jalama Formation about 2800 feet south of the surface trace of this fault, penetrated that formation to about 3000 feet, passed through the fault at that point, then entered the "Coldwater" Sandstone. This indicates a southerly dip of about 46° on the fault plane at that point.

Eastward from Hilton Canyon the dip of the Santa Ynez (southern) fault steepens to about 50° south at the mouth of Bear Canyon. Between the mouths of Hot Springs and Lewis Canyons the fault is concealed by alluvium, but is probably steep. Between Lewis and Blue Canyons, the fault probably dips steeply south, if it is not vertical, and from Blue Canyon eastward it probably is vertical. Farther east it dips steeply north in both forks of Matilija Canyon, Ventura County.

Throughout the area between Tequepis and Blue Canyons, the Santa Ynez fault brings Upper Cretaceous and Eocene rocks of the mountain block on the south up against north-dipping formations ranging in age from Eocene to upper Miocene on the northern

block. In Blue Canyon, the fault brings the Franciscan and Jalama Formations on the south against Eocene rocks overlying the Espada Formation on the north.

In the west fork of Blue Canyon is a narrow sliver of Franciscan rocks along the fault zone, and in the east fork, a sliver of serpentine. Farther east, a sliver of Eocene rocks passes eastward beyond the border of the district.

Sliver of Franciscan rocks south of Blue Canyon. Just south of the east fork is a mass of highly disturbed and sheared Franciscan rocks a mile wide and 4 miles long. This mass is bounded on the north by the Santa Ynez fault, and on the south by a branch of this fault that is apparently a reverse fault dipping very steeply north. The sheared mass of Franciscan rocks has probably been squeezed as a semi-plastic mass or "cold intrusion" from below along the Santa Ynez fault. Page, Marks, and Walker (1951, p. 1778) consider this mass to have been squeezed upward from the core of a former anticline, and state:

"The reaction of the Franciscan rocks to the various disturbances is shown by their 'churned up', sheared condition, (Fig. 16). The writers believe that the shale, graywacke, greenstone, and other lithologic members were largely *squeezed* upward as a sheared heterogeneous intrusion. According to this view, the principle Franciscan mass in the area is the core of a piercement fold which since has been largely modified (see cross-section CDE). The Tertiary strata at the south may be regarded as the overturned limb of an anticline. The crest may have existed more or less directly above the present exposure of Franciscan rocks, but it has been eroded away. Significantly, the Franciscan mass protrudes into the Tertiary formations at a place where the latter have been pushed into an overturned position near Romero saddle; in other words, it seems to have burst through where the stress and strain were greatest. This must have taken place during the severe Pleistocene orogeny, but it may have begun during one of the earlier movements."

While it is certainly possible that the Franciscan mass may have been squeezed up the core of a former anticline, it seems unlikely in this case because there is no room between the Franciscan mass and the Santa Ynez fault for the north flank of an anticline in thousands of feet of Cretaceous and Teritary formations. For this reason it seems more likely that this churned up mass of Franciscan rocks was squeezed up along the Santa Ynez fault, after and not before its inception, and that this eventually resulted in the southward push and overturning of the adjacent upturned younger formations.

Of especial significance is the flexure formed in the vertical beds adjacent to the branch of the Santa Ynez fault that curves southeastward into Romero Saddle, and that bounds the Franciscan mass on the southwest. West of this fault the vertical east-trending Cretaceous and Eocene strata curve abruptly northeast and strike directly into this fault. This relationship suggests left-lateral drag movement on this fault, probably after the Franciscan mass was squeezed up.

Amount and direction of displacement. The total displacement on the Santa Ynez fault in this district is not measurable in feet because the block north of the fault is so vastly different in stratigraphic section and structure from the block to the south. From this condition, as well as the wide shear zone along the fault, it is apparent that the displacement is very great and must amount to several miles throughout the district. While the major displacement is probably vertical with upward movement of the southern block, a large amount of left lateral displacement or eastward displacement of the southern block relative to the northern block is suggested from the following facts: 1) this fault has many characteristics of the San Andreas fault and other strike-slip faults, such as, its generally steep to vertical dip, its straight trace, the fault slivers, and topographic alignment of notches and deflected stream-courses; 2) the trend of fold axes on both sides of the fault is west-northwest, as compared to the nearly east-west trend of the fault throughout its entire course; 3) the great difference in the stratigraphic section north of the fault as compared to that south of it, especially near Blue Canyon and Wons Canyon, which decreases westward toward Gaviota Pass as displacement on the fault decreases.

From the above evidence it is concluded that the Santa Ynez mountain block has moved upward and eastward on the Santa Ynez fault relative to the block on the north, for a total oblique displacement of several miles.

Coastal Plain Area

General Structure

The structure of the coastal plain area is basically the continuation of the southward-dipping homoclinal structure of the Santa Ynez Range, but in the Oligocene and Miocene formations that overlie the Eocene rocks of the mountain range. In the coastal area, however, the homoclinal structure is broken by many faults that are generally parallel to the range, and the sediments are locally compressed into folds with axes trending west-northwest to due west. The Plio-Pleistocene formations that unconformably overlie the southward tilted Tertiary formations are generally flat-lying or only slightly tilted, and are involved in the faulting that breaks this strip into narrow blocks.

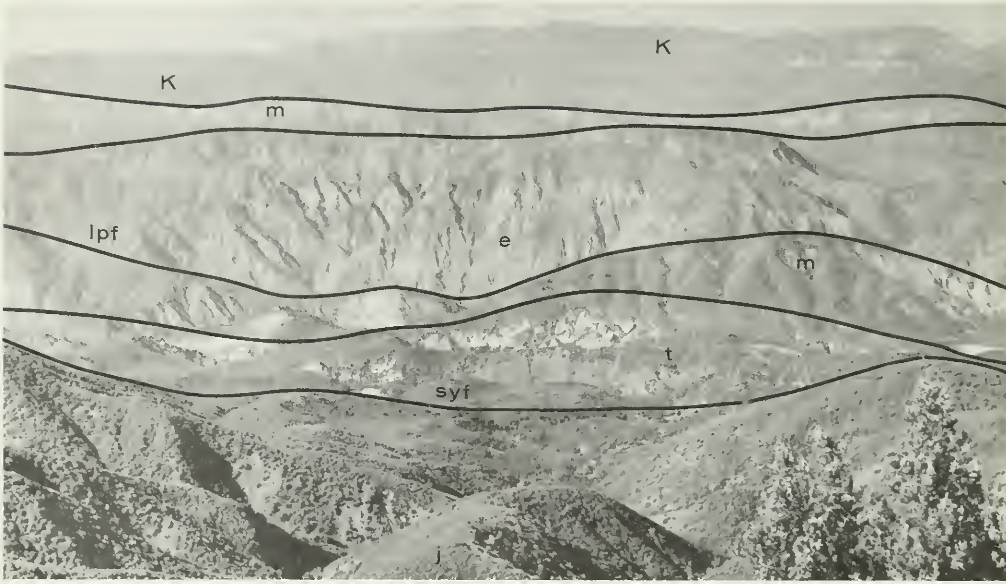


Photo 21. View north from La Cumbre Peak toward San Rafoel Mountains. Gibraltar Dam at extreme right. Shows the following formations: Juncal Shale (j) in foreground; "Temblor" sandstone (t); Monterey Shale (m); Espada Formotion (e) on Camuesa Ridge; and Cretaceous formations (K) in distance on Big Pine Mountain Ridge.

Folds

Folds in vicinity of Carpinteria Valley. In the Santa Ynez Mountain foothills north of Carpinteria Valley is a large syncline, referred to by Lian (1954, map sheet 25) as the Arroyo Parida syncline, in the Sespe Formation. The north flank is overturned southward, the south flank dips gently, and the axis trends west, with slight westward plunge. It is flanked on the south by an asymmetric anticline (Snowball anticline of Lian, 1954, map sheet 25) exposing the underlying "Coldwater" Sandstone and broken along or near its axis by the Arroyo Parida fault. Northeast of Summerland this anticline plunges west and probably cancels out with the Arroyo Parida syncline under Montecito Plain.

At Summerland is another minor fold in the Miocene shales, composed of a syncline and an anticline to the south. The latter is much faulted, as indicated from oil test holes drilled into it. On the beach is still another fold in the Pleistocene Casitas Formation that is exposed on the sea cliffs just west of and a mile southeast of Summerland. At the latter place the anticline is broken by a small, recently active thrust fault dipping about 45° south, which forms the north-facing scarp of a small hill adjacent to the sea cliff.

The Monterey Shale exposed on the sea cliffs southeastward from Carpinteria is generally vertical, but is locally buckled by numerous tiny folds. The underlying Rincon Shale is to the north and is buried by older alluvium; however, it was encountered in several oil test wells south of the Carpinteria fault. The overlying Sisquoc shale is offshore to the south.

Folds in vicinity of Goleta Valley. In the Santa Ynez Mountain foothills near Goleta Valley are several folds in the Sespe and Vaqueros Formations, as shown on the geologic and tectonic maps. All have axes trending west to west-northwest, and have gently dipping flanks. At least one of these, the Tecolete anticline, is closed where it is crossed by the canyon of that name.

The Elwood anticline as exposed on shore is a rather tightly compressed east-plunging fold in Monterey Shale. At the axis the shales are contorted, and both flanks dip about 50 degrees. Its subsurface structure is described under Mineral Resources.

Folds in coastal mesa. In the elevated coastal fault block southwest of Goleta basin is a large syncline in the Sisquoc and "Pico" Formations. The axis lies under the thin mantle of alluvial sand just inshore from the low sea cliff between Coal Oil and Goleta Points,

and passes offshore in both directions. It is flanked on the south by a probable anticline whose axis is just offshore, but several oil test holes drilled into this anticline indicate that it is complexly faulted.

Along the coastal mesa from Goleta Slough to Breakwater Beach are several small folds in the Miocene shales, as shown on the geologic and tectonic map. The axes of all these folds trend west-northwest, diagonal to the More Ranch fault, to which they are probably subsidiary. The largest of these folds is the More Ranch anticline at Goleta gas field. Another fold, not exposed at the surface, is monoclinal and produced oil from the Vaqueros Sandstone at the now abandoned Santa Barbara Mesa oil field.

Faults

Faults north and northwest of Goleta Valley. The many faults in the foothill area north and northwest of Goleta Valley are all vertical or nearly so, and trend west to west-northwest, as seen from a glance at the geologic and tectonic map. Most of these were described and named by Hill (1932, pp. 550–555). Displacements on most of them are probably mainly vertical, although low-dipping grooves on some, as observed by Hill (1932, pp. 550–555), if consistent, suggest large components of lateral displacement. On most of these faults the relative upthrown block is on the south, as on the Santa Ynez fault, but on a few the upthrown block is on the north, as on Dos Pueblos fault and part of the Glen Anne fault. The largest fault is the Cameros, traceable for 8 miles; it shows a relative upward maximum vertical displacement of the south block of about 1600 feet. The San Jose fault may be equally large, and at its southeastern end the southern block is elevated so that it forms a small north-facing scarp in fanglomerate and exposes the underlying Rincon and Santa Barbara Formations. In the alluviated part of Goleta basin several other minor faults, postulated on differences in the underground water level, are described by Upson (1951, pp. 26–28; pls. 1 and 2).

More Ranch fault. The More Ranch fault, named by Hill (1932, p. 554) bounds on the north the elevated coastal fault block south of Goleta basin. The coastal block has been elevated, relative to the northern block, 2,000 feet or more since or during deposition of the Santa Barbara Formation, as indicated by data from wells drilled on opposite sides of the fault in the vicinity of Goleta gas field (see cross-section DD′). The displacement decreases to the west, and the fault eventually dies out into the north flank of the Elwood anticline. The dip on this fault plane is not definitely known, but it is probably steep, possibly to the south. Apparently this fault was recently active, as late movements on it must have produced the north-facing scarp that forms the northern edge of the coastal mesa. The small north-facing scarp at the east end of the Elwood oil field was likewise produced by movements on this fault—or an extension of it—which is exposed on the sea cliff, where it dips about 45° south.

Northwest of Santa Barbara the More Ranch fault apparently divides into two parts, one branch extending east to become the Mission Ridge fault, the other extending southeast to become the Mesa fault. Another fault, the Lavigia fault, branches off from the More Ranch fault at a point 2 miles east of Goleta.

Lavigia fault. The Lavigia fault, named by Willis (1925, map) is traceable for about 4 miles southeastward from its juncture with the More Ranch fault. It is within the hills of "the Mesa" and is about a mile southwest of the Mesa fault. The Lavigia fault is nowhere clearly exposed and is not expressed topographically, but evidence of its existence is the continuous exposure of Miocene formations on the relatively elevated southwestern block and of the Santa Barbara Formation on the northeastern block. The fault appears to dip steeply northeast. Maximum displacement is quite large, for a well drilled in the Santa Barbara Formation just north of the fault and east of San Roque Creek passed through 2,100 feet of this formation, which is almost completely missing on the elevated southwestern block. Southeastward the displacement diminishes rapidly and the fault dies out, possibly into a small fold in the Monterey Shale exposed in the sea cliff.

Mesa fault. The Mesa fault, named by Willis (1925, p. 258, map) is nowhere exposed, but the steep northeast-facing escarpment of "the Mesa" southwest of the city of Santa Barbara is inferred to be the result of faulting. This escarpment of the elevated southwestern block of this supposed fault exposes the Sespe Formation, overlain unconformably by the Santa Barbara Formation. The city of Santa Barbara is on the alluviated plain of the relatively depressed northeastern block of this fault, and the alluvium of the plain is underlain by an unknown thickness of the Casitas and Santa Barbara Formations. Another indication of the Mesa fault is in the anomalous steep northeast dips in the Santa Barbara Formation along the supposed trace fault about a mile east of San Roque Creek. The approximate location of this fault is as shown; it may extend an unknown distance eastward offshore, possibly to the Carpinteria fault.

Mission Ridge fault. An alignment of low north-facing scarps that bound a low mesa of fanglomerate

northwest of Santa Barbara, the north side of Mission Ridge, and the north side of the hills east of Sycamore Canyon, strongly suggests the presence of a fault, referred to as the Mission Ridge fault.

The fanglomerate that covers Mission Ridge, and that slopes under the city of Santa Barbara, must be the lower part of the old southward-sloping alluvial fan between lower Rattlesnake Canyon and Sycamore Canyon disrupted by displacement on the supposed Mission Ridge fault. North of the fault the alluvial fan is not deformed; its top surface slopes about 10° south. Where the fan is apparently broken by the fault there is a north-facing scarp on the north side of Mission Ridge, which was apparently elevated as a block on the south side of the fault. The fanglomerate extends over the very top of Mission Ridge, as well as down its gentle south slope, and remnants cap the high hill east of Sycamore Canyon. The fanglomerate could not have been deposited at such isolated high positions; therefore, it must have been elevated to these positions by faulting. On both sides of Mission Ridge the fanglomerate overlying the Monterey Shale is locally tilted as much as 35° away from the crest of the ridge.

Vertical movement on the Mission Ridge fault as indicated by displacement in the fanglomerate amounts to several hundred feet. The total displacement may be much greater, but is difficult to determine in the underlying Miocene formations because the fault is probably parallel or nearly parallel to the vertical attitude of the beds. This makes it difficult to detect the presence of the fault in these beds, although the apparent repetition of the Rincon-Monterey contact may indicate its position.

Arroyo Parida fault. The Arroyo Parida fault trends eastward through the hills north of Carpinteria Valley. It has been traced eastward for about 10 miles into the adjoining Ventura quadrangle. It extends westward for an unknown distance under Montecito Plain, possibly to the Mission Ridge fault with which it is aligned. The southern block, which exposes southward-dipping "Coldwater" Sandstone below the Sespe red beds, has been displaced upward nearly 1,000 feet relative to the northern block, which exposes Sespe red beds dipping north. The southern block may also have been displaced eastward relative to the northern block as suggested by eastward deflection along the fault of several southward-trending stream channels, including Arroyo Parida Creek and several others just east of the map area. The fault plane dips steeply north; dips of about 60° were measured in several canyons just beyond the eastern border of the map area.

Carpinteria fault. The fault that passes south of east under the town of Carpinteria, as mapped by Upson (1951, pl. 1), is named the Carpinteria fault. This fault, together with one branching eastward from it, bounds the Carpinteria Basin on the south, and extends westward an unknown distance offshore, possibly to the Mesa fault. Vertical displacement on the Carpinteria fault amounts to several thousand feet, as Monterey Shale on the elevated southern block is exposed along the sea cliffs; also, on the relatively depressed northern block, two oil test holes penetrated the Casitas and Santa Barbara Formations to depths below 2,000 feet. Two other test holes (B24 and B29) drilled on the elevated southern block passed through upturned Miocene formations into the Santa Barbara Formation which they penetrated to depths below 3,000 feet. Within the map area this fault is not exposed, but 2 miles south of east of Carpinteria it is exposed on the highway cut, where vertical Monterey Shale is thrust northward against loosely consolidated sand of the older alluvium, indicating that the fault was recently active. Just east of Carpinteria another fault, the Rincon Creek fault of Lian (1954, map sheet 25) branches off from the Carpinteria fault and extends eastward to Rincon Creek. This fault is within the Casitas Formation and the southern block is likewise upthrown.

San Marcos Block

General Structure

The San Marcos block is a relatively stable wedge-shaped block between the elevated Santa Ynez Mountain block to the south and the Little Pine Mountain block to the northeast. The southeastern apex of this wedge includes the much disturbed strip of the Santa Ynez River Canyon area between these two elevated mountain blocks as far southeast as the Juncal Camp fault in Blue Canyon.

The major structure of the San Marcos block is that of a synclinal trough plunging gently northwest. This structural trough exposes the Plio-Pleistocene series, and the unconformably underlying upper and middle Miocene sequence on its flanks and in the Santa Ynez River Canyon area. On the south flank of this trough the upper-middle Miocene sequence rests unconformably on the lower Miocene-Oligocene-Eocene series and Espada Shale, but on the north flank in lower Redrock and Oso Canyons it rests directly on the Franciscan rocks. An oil test hole drilled near Cachuma Canyon on the San Marcos anticline passed from "Temblor" sandstone directly into serpentine. It is therefore probable that in most places north of the axis of this structural trough the Miocene formations are underlain by Franciscan rocks.

Folds

Folds west of Bear Canyon. North of the Santa Ynez fault the formations exposed in the Santa Ynez

River area as far east as Blue Canyon dip generally northward into the axis of the synclinal trough of the San Marcos block. However, in the area westward from Bear Canyon are several folds in the Monterey Shale, with axes trending west-northwest, nearly parallel to the Santa Ynez fault. The largest of these structures is a syncline whose axis lies nearly 2 miles north of the Santa Ynez fault, and whose south flank is steep and locally overturned to the north by pressure from the Santa Ynez Mountain block. This syncline is flanked on the north by a strongly compressed anticline, the Tequepis anticline, that lies south of the Cachuma Reservoir. Northwest of this fold is another similar anticline. Both these anticlines have steep north flanks, and oil test wells drilled on each encountered Eocene formations below the "Temblor" sandstone. This group of folds extends westward into the adjoining Los Olivos quadrangle and becomes part of the structural block referred to as the "northern Santa Ynez Mountain block" (Dibblee, 1950, pp. 53–54).

Los Alamos syncline. The major axis of the synclinal trough of the San Marcos block is the axis of the Tequepis syncline of Nelson (1925, pl. 1), which is really the axis of Los Alamos syncline, which extends southeastward from Los Alamos and upper Santa Ynez Valleys, Los Olivos quadrangle, (Dibblee, 1950, pl. 7). In the northwestern part of the district this large fold plunges gently westward toward upper Santa Ynez Valley and involves the Paso Robles Formation, in which dips gradually flatten as the axis is approached.

Folds in Santa Ynez River Canyon area. The axis of Los Alamos syncline is traceable as far to the southeast as the Santa Ynez River near the mouth of Redrock Canyon. At that point an anticline appears northeast of this syncline, rises southeastward to expose Monterey Shale, and becomes tightly squeezed and partly overturned toward the south. Southeastward it eventually cancels out with the Los Alamos syncline under the Santa Ynez River about 3 miles southeast of the mouth of Redrock Canyon.

Northeast of the above described anticline is another syncline, referred to as Los Prietos syncline, which becomes the main axis of the trough of the San Marcos block from lower Redrock Canyon to Gibraltar Dam. This syncline, in the Monterey Shale on the north side of the Santa Ynez River, becomes very tightly squeezed, especially near the mouth of Oso Canyon; it is partly overturned southward.

Immediately northeast of Los Prietos syncline is a large asymmetric anticlinal uplift in the Miocene rocks across lower Oso and Redrock Canyons; however, the underlying Franciscan and Eocene rocks all dip northeast. Loma Alta Ridge is the topographic expression in the Monterey Shale of the west-plunging nose of this anticlinal uplift. Southeastward the Monterey Shale exposed in the steep hills north of the Santa Ynez River represents the vertical south flank of this anticlinal uplift. East of Oso Canyon the anticlinal structure in the Miocene strata plunges southeastward, rises again at Gibraltar Dam, then cancels out with Los Prietos syncline.

The Eocene and Miocene formations on the northeastern flank of the above-described anticlinal uplift dip gently into an asymmetrical syncline, here referred to as the Oso syncline, whose axis lies close to the Little Pine fault. On the northeastern flank of this syncline the Eocene and Miocene formations are vertical or steep, and this flank is partly overridden by the Little Pine overthrust block from the northeast. Southeast of Redrock Canyon this asymmetrical syncline plunges gently southeast, and southeastward from Gibraltar Dam the axis becomes the main axis of the trough of the San Marcos block.

Faults

Faults south of Santa Ynez River. In the northern foothills of the Santa Ynez Range between Tequepis and Bear Canyons are four high-angle faults, and near the Santa Barbara Reservoir are three others. All are within a mile north of the Santa Ynez fault and trend generally north of west. All but the easternmost are strike-faults in north-dipping beds, and in each case the northern block has been displaced relatively upward, causing repetition of strata. The easternmost occurs near the axis of an anticline and its southern block is displaced relatively upward. All of these faults appear to be dip-slip faults with no evidence of lateral displacement. Maximum vertical displacement is 1,000 feet or less.

Loma Alta fault. The Loma Alta fault, not recognized by Nelson (1925), is an offshoot of the Little Pine fault, branching off from it in Horse Canyon, trending south along the western base of Loma Alta, then curving southeastward. This fault is exposed in several small canyons, where it can be seen to dip at a low angle to the northeast; but in most places it is covered by landslides of shale from up-slope. Along this fault the Monterey Shale of Loma Alta has partly or completely overridden the Tequepis and Careaga Sandstones onto the Paso Robles Formation. Maximum displacement amounts to about 1,000 feet; displacement decreases to the southeast, as the fault dies out into beds overturned southward in Redrock Canyon.

"*Redrock fault*". Across lower Redrock and Oso Canyons the so-called "Redrock fault" was mapped

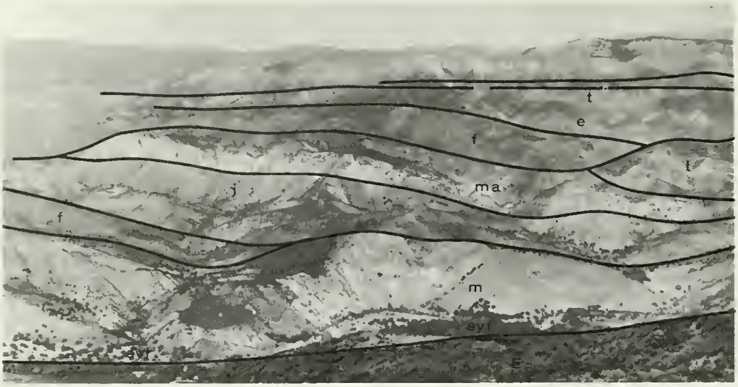


Photo 22. View north from Santa Ynez Range north of Pointed Cave toward San Rafael Mountains. Oso Canyon and Little Pine Mountain at right. Shows the following formations: Eocene formations (E) in foreground; trace of Santa Ynez fault (syf); Monterey Shale (m); Franciscan Formation (f); Juncal Shale (j); Matilija Sandstone (ma); Espada Formation (e); Temblor Sandstone (t); and Cretaceous formations (K).

along the axis of the anticlinal uplift between the Oso and Los Prietos synclines, at the contact of the Franciscan and upturned Temblor and Monterey formations by Kew (1919, pl. 1, p. 17), and copied by Nelson (1925, pl. 1, p. 389). However, closer inspection of this contact indicates it to be essentially an angular unconformity between the Franciscan and Temblor-Monterey series upended into a vertical position, giving the false impression of a fault. Some minor faulting occurs along or near this contact, but this is only the result of buckling of the upended Monterey Shale.

Little Pine Mountain Block

General Structure

The Little Pine Mountain block, like the Santa Ynez Mountain block, is elevated on a major thrust or reverse fault, the Little Pine fault, which dips under it; but instead of being tilted away from the fault along which it was elevated, the block is elevated as a series of large folds parallel to the fault. Adjacent to the Little Pine fault, the mountain block exposes a strip of intensely sheared Franciscan rocks. These rocks are overlain by an enormously thick series of Cretaceous and Eocene strata that are compressed into several large folds with axes trending west-northwest and plunging southeast. This strongly folded sequence of strata is overlain unconformably by a relatively thin Miocene sequence that is less strongly compressed into open folds, and that is preserved only as erosional remnants in two of the major synclines.

Folds

Mono syncline. The Franciscan rocks exposed on the northeast side of the Little Pine fault are overlain by the Espada Formation dipping steeply northeast into the axis of the Mono syncline that plunges gently southeastward. In the northwestern part this fold is broken along the axis by the Camuesa fault; to the southeast the axis goes into the Juncal Camp fault.

Agua Caliente anticline. The Mono syncline is flanked on the northeast by the Agua Caliente anticline. This is a major fold traceable from Camuesa Canyon for some 13 miles southeastward into the mountains east of Agua Caliente Canyon, where it dies out between two synclines. In the western part of this anticline, dips in the Espada Formation on both flanks are very steep, ranging from 60 to 90 degrees; the plunge is likewise steep, ranging from 50 to 70 degrees. Eastward the dips and plunge in the Cretaceous and Eocene Formations flatten to an average of about 30 degrees.

On the southwest flank of the Agua Caliente anticline east of the mouth of the canyon of that name is a subsidiary syncline, referred to as the Juncal syncline, and a complementary anticline, the Pendola anticline, in the Juncal Formation. This fold plunges southeast and the Pendola anticline is partly overturned to the southwest. Northwestward from the Pendola anticline Page, Marks, and Walker (1951, map) infer the presence of a fault across the mouth of Agua Caliente Canyon on the steep southwest flank of the Agua Caliente anticline and along the contact of the Juncal (?) and Espada Formations. However, the presence of a fault along this contact could not be ascertained, as the contact seems more likely to be an angular unconformity upturned into an almost vertical position.

Little Pine syncline. The Agua Caliente anticline is flanked on the northeast by a major southeast-plunging syncline that passes through Ogilvy Ranch. This fold extends northwest in the Espada Formation under the Miocene formations of Little Pine Mountain, after

which it is named. The structure of the Miocene strata of Little Pine Mountain is a syncline with gently dipping flanks; it is located just north of the district mapped. To the southeast, the Little Pine syncline within the Eocene formations merges with the syncline north of Juncal Dam.

Folds northeast of Little Pine syncline. The Little Pine syncline is flanked on the northeast by another major anticline in Cretaceous formations plunging southeast up Diablo Canyon, after which it is named. This fold is asymmetric, dipping 70 to 90 degrees on the southwest flank and 45 to 60 degrees on the northeast flank. North of this anticline is another major southeast-plunging syncline.

Faults

Little Pine fault. The Little Pine fault is a major northwest-trending thrust or reverse fault along which the Little Pine Mountain block was elevated. This fault is traceable for some 16 miles northwestward beyond the west border of the mapped district, along the southwestern base of the San Rafael Mountains to Zaca Canyon. Within the district it is traceable for 27 miles terminating on the southeast against the Juncal Camp fault. Along the Little Pine fault the Franciscan rocks have overridden Eocene and Miocene formations of the Oso syncline to the southwest.

The elevated northeastern block of the Little Pine fault forms a mountain front that is steep and abrupt on the southwest slope of Camuesa Ridge. Farther northwest, the mountain front is less steep in the Franciscan rocks, but rises abruptly in the overlying formations to the ridge of Little Pine Mountain. The fault itself is expressed as an alignment of notches across ridges and by small subsequent tributaries of the major creeks. Between the mouths of Camuesa and Blue Canyons the Little Pine fault is marked by a fault-line scarp along which the relatively elevated northeastern block that exposes easily eroded Espada shale is topographically lower than the southwestern block that exposes more resistant Monterey Shale.

The Little Pine fault is marked by a zone of gouge and sheared rock as much as 50 feet wide. The fault dips about 25° northeast in Redrock Canyon and near Santa Cruz Creek. Southeastward it steepens to about 45° northeast in Oso Canyon, and to 60° to 90° along the Santa Barbara Reservoir.

The amount of total displacement on the Little Pine fault is not known, but it must be great, for Eocene strata lie directly on the Franciscan Formation southwest of the fault. Northeast of the fault, the Eocene strata rest on many thousands of feet of intervening Cretaceous strata. Perhaps this condition may have resulted in part from lateral as well as vertical displacement. Within the mapped district the total displacement must amount to several thousand feet, decreasing to the southeast.

Camuesa faults. About a mile northeast of the Little Pine fault, in Upper Oso and Camuesa Canyons, are two closely spaced faults that bound a narrow strip of Franciscan rocks. The northeastern and larger of these two faults separates the main mass of Franciscan rocks on the southwest from Espada shale on the northeast. This fault is traceable for some 9 miles northwest to Santa Cruz Creek, where part of it was mapped by Nelson (1925, pl. 1). He did not name it.

This fault appears to be practically vertical. The Espada beds adjacent to it are generally vertical or locally overturned northward, and strike westward diagonally into the Franciscan rocks across it. Along this fault the southwestern block has been displaced upward and/or northwest, relative to the northeastern block. The amount of displacement is not known, but it is probably several thousand feet. Displacements on minor parallel vertical faults to the northeast are similar, but on a small scale, as indicated by offset sandstone beds.

On the southwestern fault, which crosses Camuesa Ridge, the northeastern block has been displaced upward and/or southeastward several hundred feet relative to the southwestern block. Southeastward in Camuesa Canyon the Camuesa fault zone dies out into the Espada Formation near the axis of the Mono syncline.

Juncal Camp fault. The Juncal Camp fault, named by Page, Marks, and Walker (1951, p. 1773), bounds on the north the hill of Espada shale north of Blue Canyon, is concave southward, and terminates at both ends against the Santa Ynez fault. It is very nearly vertical, and the block of Espada shale on the south has been elevated perhaps several thousand feet, relative to the northern block. The Espada shale of this block is practically vertical. The presence of a small body of serpentine in the shale near the middle of the western part of the block, and the steep eastward dips in the shale east of this serpentine body, suggest the Espada shale is compressed into an isoclinally folded southeast-plunging anticline, whose axis appears to be in line with the Little Pine fault to the northwest.

Hildreth fault. The Hildreth fault, first recognized by Nelson (1925, pl. 1), is at the southwestern base of Hildreth Peak and extends north of west across Mono and Indian Creeks. It terminates on the southeast against the Munson Creek fault. Along the fault, Cretaceous rocks on the north block are displaced upward several hundred feet against Monterey Shale on the

south block. The Hildreth fault dips steeply north to vertical.

Munson Creek fault. The Munson Creek fault, named for exposures at the mouth of Munson Creek near Sespe Gorge, 11 miles beyond the eastern border of the Hildreth quadrangle, is a 25-mile-long west-trending fault of which the western 7 miles lies within the Hildreth Peak quadrangle. In this area it is within Cretaceous rocks and dies out into a sharp anticline. It is marked by an alignment of notches and its straight trace indicates that it is practically vertical. Near and beyond the eastern border of the map area the south block is displaced upward relative to the north block. The west end of the large anticline and syncline on the south block in Agua Caliente Canyon appears to be offset as much as a mile to the west, on the north block (see map), suggesting left lateral displacement.

Tectonic Implications

Tectonic development of Santa Ynez Mountain block. The Santa Ynez Mountain block is a segment of probable Franciscan rocks overlain by a great thickness of Cretaceous, Eocene, Oligocene, and lower Miocene sediments, and was uplifted along the Santa Ynez fault and shoved northward or northeastward toward and against the adjacent San Marcos and Little Pine Mountain blocks. The segment of the earth's crust that formed the Santa Ynez Mountain block may have started to rise as an anticlinal uplift, as suggested by Page, Marks, and Walker (1951, p. 1778)—or as a southward-tilted block on the Santa Ynez fault that formed as a great rupture in the earth's crust prior to any folding. However, as this segment of the earth's crust started to rise, it became a southward-tilted block that formed the Santa Ynez Range. The mountain block did not rise uniformly along the Santa Ynez fault, but partly as two masses separated by the structural saddle that now forms San Marcos Pass, where several folds formed with axes trending northwest, diagonal to the Santa Ynez fault. In the coastal area, the southward-tilted strata were disrupted by minor breaks, generally parallel to the Santa Ynez fault to the north, and were locally compressed into small folds with axes trending west to west-northwest. The dominant force that elevated the Santa Ynez Mountain block, as indicated by this structural pattern, must have been compressive and directed from a south-southwest direction. However, evidence of a left-lateral component of movement on parts of the Santa Ynez fault that are vertical and trend eastward indicates a counter-clockwise tortional or rotational force may have been involved in the uplift of this mountain block.

The folds in the San Marcos Pass area, whose axes trend diagonally into the Santa Ynez fault, appear to be the result of eastward-lateral drag movement of the Santa Ynez Mountain block as it was pushed up along the Santa Ynez fault diagonally northeastward against the adjacent San Marcos block. If this is so, these folds were formed contemporaneously with the Santa Ynez fault. There is no evidence to support Kew's hypothesis (1919, pp. 16, 17) that these northwest-trending structures were formed prior to the east-trending structures, such as the Santa Ynez fault, and by a separate force acting in a different direction.

In the coastal area, the line of east-trending faults formed by the More Ranch, Mission Ridge, and Arroyo Parida faults, is another break similar to the Santa Ynez fault, with the same type of displacement, but on a smaller scale. The Mesa and Carpinteria faults may belong to this same system. The folds in the Miocene formations on the coastal block south of the More Ranch fault, with axes trending west-northwest diagonally into this fault, were probably formed by eastward-lateral drag movement of the coastal block on the More Ranch fault in exactly the same manner in which the folds of the San Marcos Pass area were formed by left-lateral drag movement on the Santa Ynez fault.

The isolated minor faults north and northwest of Goleta Valley that trend west to north of west, and that are not aligned, appear to be dip-slip faults. Most are strike faults in south-dipping beds; where the faults are oblique to the strike they are at or near zones of changes of dip, and bound on the north minor elevated fault blocks within the Santa Ynez Mountain block. Most show no definite topographic or structural evidence of lateral movement, although Hill (1932, pp. 550–555) found fault grooves on several faults that dip at low angles, suggesting that lateral components of movement may have been greater than vertical components on those particular faults, at least locally. If so, then those faults may have been formed in part by the same forces that formed the Santa Ynez fault and the More Ranch-Mission Ridge-Arroyo Parida fault system.

Tectonic development of San Marcos block. The San Marcos block, although structurally a synclinal trough, is regionally a "high" in which the post-Franciscan sedimentary series is thin, compared to the equivalent series on the adjacent mountain blocks. The San Marcos block has been stabilized by at least three orogenic disturbances during the Tertiary period. During that period the Cretaceous and Eocene sedimentary series, which are so thick in the adjacent mountain blocks, were partly or wholly removed from

the San Marcos block. As a result, middle Miocene strata are underlain directly by the Franciscan rocks in the northern part of the San Marcos block. In the severe diastrophism of the Quaternary period, the central and major portion of this stabilized block resisted upheaval, so that only the marginal portions were affected by drag movements from uplift of the adjacent mountain blocks.

On the southern margin of the San Marcos block the formations have been upturned and tilted to the north by pressure from the uplifted Santa Ynez Mountain block to the south. Between Hilton and Bear Canyons, southward pressure from the mountain block was especially severe; for beds adjacent to the Santa Ynez fault have been upturned vertically, or even overturned northward, and all folds in the Monterey Shale to the north have been pushed northward into asymmetric positions with steepened north flanks. The minor strike-faults in these steep north-dipping sedimentary series with upthrown blocks on the north were probably formed by the sediments breaking into blocks that rode up against each other as the series was pushed up and tilted northward. These faults were formed in the same manner as similar strike-faults farther west in the vicinity of Nojoqui and Alisal Canyons, Los Olivos quadrangle (Dibblee, 1950, p. 57, fig. 5).

The northeastern margin of the San Marcos block was severely affected by pressure from the Little Pine Mountain block. This is indicated by the intensely compressed asymmetric anticlines, with their oversteepened southwest flanks, in the Santa Ynez River area between the mouths of Redrock and Blue Canyons. The large asymmetric anticline exposing Franciscan rocks between Loma Alta and Oso Canyons, was elevated in front of the Little Pine Mountain block by severe pressure from it, as indicated by the vertical attitude of the Miocene strata on the southwestern flank.

Tectonic development of Little Pine Mountain block. The Little Pine Mountain block, a segment of Franciscan rocks overlain by a great thickness of Cretaceous and Eocene marine sediments, was uplifted along the Little Pine fault and shoved south or southwest toward and against the adjacent San Marcos block. This mountain mass may have started to rise as an anticlinal uplift along what is now the Little Pine fault, and may have been elevated, not as a tilted block, but as a series of successive parallel major folds in the post-Franciscan rocks. As the Little Pine fault and the axes of the folds in this mountain mass are inclined to the north-northeast, the force that elevated it must have been directed mainly from that direction. However, evidence of right lateral movement on the Camuesa faults, on other minor ones nearby, and on the Little Pine fault north of the district, indicates that a clockwise tortional or rotational force, as well as a compressive force, was involved in the uplift of the block.

Tectonic relations of blocks within the district. Where the uplifted Santa Ynez Mountain and Little Pine Mountain blocks were in contact with the comparatively stable San Marcos block, the greater part of the regional stress that uplifted them was relieved through movement via the Santa Ynez and Little Pine faults toward the San Marcos block. A minor part of this stress was distributed, through folding and faulting, within the uplifted mountain blocks and along the uplifted margins of the San Marcos block.

Where the two mountain blocks approach each other across the narrow southeastern apex of the San Marcos wedge from lower Redrock Canyon to Blue Canyon, the great south-southwest force that elevated the Santa Ynez Mountain block and the north-northeast force that elevated the Little Pine Mountain block begin to bear on each other. This is indicated by 1) the gradual bending of both the Little Pine and Santa Ynez faults so that they are nearly parallel and trending west-northwest; this is not quite normal for these two major faults, especially outside the mapped district —as can be seen from a glance at the geologic map; 2) the steepening of both faults, and 3) the tightly folded condition of the Tertiary sediments in this part of the San Marcos block between these two uplifted mountain blocks.

The bending of the 9-mile segment of the Santa Ynez fault between San Marcos Pass and Blue Canyon into a somewhat anomalous west-northwest trend may be of especial significance. No other part of the Santa Ynez fault has this trend—with the exception of the small segment north of Santa Ynez Peak. This suggests that the Santa Ynez fault and the adjacent Santa Ynez Mountain block may have been bent out of line from their normal easterly trend by a clockwise rotational or torsional force active at depth along the vicinity of the Little Pine fault. If so, the Santa Ynez fault has swerved out of line in exactly the same manner in which the San Andreas fault has swerved out of line where it is intersected by the Garlock and Big Pine faults: by left lateral movement on these two faults (Hill and Dibblee, 1953, p. 453, pl. 4).

Similarly, the southeastern 9-mile segment of the Little Pine fault may have been forced from its normal southeast trend almost due east by a counterclockwise rotational force active throughout the vicinity of the Santa Ynez fault at depth.

Photo 23. View northwest from Santa Ynez Mountains toward Lama Alta (center). Shows the following formations: Eocene formations (E) in foreground; trace of Santa Ynez fault (syf); Paso Robles Formation (pr); Monterey Shale (m); Matilija Sandstone (ma); Juncal Shale (j); Franciscan Formation (f); and Cretaceous formations (K).

Eastward from the point where the San Marcos block wedges out at Blue Canyon, the Santa Ynez and Little Pine Mountain blocks come in direct contact along the eastern segment of the Santa Ynez fault. In this area, the two great forces that uplifted these two mountain blocks are in direct opposition, and affect each other strongly. The termination of the Little Pine fault at this juncture, and the continuation of the Santa Ynez fault some 40 miles beyond (eastward), suggest that the south-southwest force, or whatever force elevated the Santa Ynez Mountain block, was greater, especially at depth. Its effect north of the Santa Ynez fault has resulted in the upturning of the Cretaceous and Eocene strata to generally vertical attitudes just north of the juncture of these two major faults. The terrific pressure at depth that resulted from the conflict of this great force with the north-northeast force (or whatever force uplifted the Little Pine Mountain block) probably caused the intense shearing and churning up of the mass of Franciscan rocks just south of the Santa Ynez fault near its juncture with the Little Pine fault and the squeezing of this churned-up mass to the surface in the form of a "cold plastic intrusion". This mass must have come from a considerable depth, and probably through a great thickness of Cretaceous sediments, as at no other place south of the Santa Ynez fault are the Franciscan rocks exposed. The southward overturning of the upended Cretaceous and Eocene formations in the Santa Ynez Range south of this squeezed-up mass of Franciscan rocks may be in part the effect of the force from the north-northeast that was transmitted southward across the Santa Ynez fault.

Past and present state of tectonic activity. The Santa Ynez and San Rafael Mountains probably started to rise during or soon after deposition of the Sisquoc Formation; continued to grow, perhaps in stages, during much of Pliocene and early Pleistocene times; and reached their climactic stage of uplift during the Coast Ranges orogeny in late Pleistocene time, when the late Pleistocene fanglomerate was deposited at their bases. They are probably still rising, but at a diminishing rate.

Most if not all of the present structures now exposed in the two mountain blocks must have formed in late Pliocene or early Pleistocene time. During the late Pleistocene orogeny these grew as pressure from stress increased, and other structures formed that involved formations deposited during early Pleistocene time.

At present, the folds in the area are probably still being compressed, and most of the faults are probably still active. Faults that are known to have been active since deposition of the late Pleistocene fanglomerate are the More Ranch, Mission Ridge, and Arroyo Parida faults; the southeastern San Jose fault, Carpinteria fault, and probably the Mesa and Lavigia faults. The Santa Ynez fault is known to be active, as indicated by deflected streams. The Little Pine fault is probably active though it is not known to have been active since late Pleistocene time. Therefore, any of these faults might possibly produce earthquakes.

It is not known which fault caused the violent earthquake that severely damaged the city of Santa Barbara on June 29, 1925, because the epicenter was not determined and no surface ruptures were formed on shore. Because the intensity of that shock was apparently greatest in the city of Santa Barbara, it is believed that the earthquake probably originated either on the Mesa fault, or its seaward projection, or possibly on some fault offshore from the city.

Strain pattern. The strain pattern within the district is shown on the accompanying tectonic map, and within the region which includes the mapped district on the geologic setting map. Within the district at least four sets of faults are postulated, based on trend, dip, and movement. These are as follows: 1) high angle oblique-slip faults trending due west or nearly

so, with left lateral components of movement; 2) reverse or thrust faults trending west-northwest; 3) high angle dip-slip (?) faults trending west-northwest to due west; and 4) high angle oblique-slip faults trending northwest, with right lateral components of movement. Hill (1932, p. 542) classified the high-angle faults in the coastal area near Goleta Valley into two local systems, each containing two sets of faults, based essentially on trends and movement as suggested by the dip of grooves found in exposures of the fault plane, together with the relative displacement.

The segment of the Santa Ynez fault within the district is a compound fault that belongs to both sets 1 and 2. The part that is a southward-dipping reverse or thrust fault trending west-northwest, westward from Gidney Canyon, belongs to set 2, whereas the part to the east that is vertical and trends due west, with evidence of left-lateral movement, belongs to set 1. West of Hilton Canyon the vertical northern fault may belong to set 1, whereas the south-dipping southern fault belongs to set 2. The More Ranch and Arroyo Parida faults, and possibly the Mission Ridge, Mesa, and Carpinteria faults belong to set 1. Most of the other minor faults on the coastal plain, and those between the Santa Ynez fault and Santa Ynez River, belong to set 3. The segment of the Little Pine fault within the mapped district belongs to set 2, although farther to the northwest it may belong partly to set 4. The Camuesa faults and the two minor ones to the northeast are the only ones within the district that belong to set 4.

The 80-mile-long east-trending Santa Ynez fault, along which the southern block has been elevated, is basically a high-angle oblique-slip fault that extends deep into the earth's crust. This fault is one of a set of several big east- or east-northeast-trending faults with left-lateral components of displacement (that is, the northern block was displaced toward the west relative to southern block) in southern California as recognized by Hill and Dibblee (1953, p. 455, pl. 1). Among these major faults are the Big Pine fault, which parallels the Santa Ynez fault about 12 miles north; the Garlock fault, that is aligned across the San Andreas fault with the Big Pine fault; and the east-trending faults on Santa Cruz and Santa Rosa Islands, which parallel the Santa Ynez fault about 30 miles south. Set 1 of the map area falls within this group.

The 40-mile-long Little Pine fault, along which the Little Pine Mountain block was elevated, follows a line of weakness in the earth's crust that extends many miles northwest along the southwestern margin of the San Rafael and Santa Lucia Mountains, as seen from a glance at the geologic setting map. The Little Pine fault is the most southeasterly of several major faults along this line of weakness. Northwest of the district several of these, including the Suey fault, trend northwest, and have steep to vertical dips; associated drag folds and offset contacts strongly suggest right lateral movement (northeast block moved relatively southeast). These faults, including the Little Pine fault (in part) and the Camuesa faults, belong to a set of steep, northwest-trending faults with right lateral components of movement that is distributed throughout much of California, as recognized by Hill and Dibblee (1953, p. 454, pl. 1). The San Andreas fault is by far the largest of this set of northwest-trending right lateral faults. Faults of set 4, mostly north of the map area, are of this group.

Within the district, as well as in adjoining districts, the axes of folds in all the sedimentary formations in all three blocks trend generally west-northwest. The overall effect of the strain pattern as expressed in the trends of fold axes, and trends and movements on the faults, is a crustal shortening in a north-northeast south-southwest direction.

Probable stresses. Such a strain pattern as outlined above may have been produced by a single regional compressive stress composed of opposing forces acting from north-northeast and south-southwest directions. The folds throughout the district and the less steeply dipping parts of the Santa Ynez and Little Pine faults that are parallel to the axes of the folds, could all have been produced by such a stress. However, evidence of lateral components of movement on the major faults suggests torsional or rotational stresses were active, possibly at greater depths. This is suggested by the fact that the folds are largely if not entirely in the post-Franciscan formations, while the major faults, such as the Santa Ynez and Little Pine, must extend much deeper into the earth's crust, probably through the Franciscan and possibly into the pre-Franciscan rocks for many miles. It seems possible that the compressive stress that formed the folds was active at comparatively shallow depths in the earth's crust, and may have been subsidiary to some greater regional stress or stresses active at greater depth that produced the major faults. The type and direction of these deep-seated stresses can only be inferred from the type of movement and trend of these major faults and other similar ones outside the district.

The Santa Ynez fault, More Ranch-Mission Ridge-Arroyo Parida line of faults, and other major east- to northeast-trending oblique-slip faults with left lateral components of movement may be the result of a deep-seated counter-clockwise rotational stress that acted from a northeast-southwest direction. The counter-clockwise rotational stress is indicated by the evidence of left-lateral movements in faults of this set. The

orientation of the stress, which is oblique to the fault trends, is indicated by the strong compression of one block against the other along these faults, as expressed in the uplift of mountain ranges along them, such as the Santa Ynez Range, and by the strongly compressed folds adjacent to these faults, with axes trending slightly oblique to the trend of the faults.

In a like manner the Little Pine fault and other major northwest-trending faults, including the San Andreas fault, with right lateral components of movement, may be the result of a great regional clockwise rotational stress probably acting from a north-south direction at great depth. The clockwise rotational stress indicated by the evidence of right lateral movements on faults of this set, and the orientation of the stress, which is oblique to their trend, is indicated by the associated compressive features such as mountain ranges and tightly compressed folds formed adjacent to these faults.

While the overall regional stress or stresses that formed the structures within the mapped district are not known, the writer is of the opinion (based on mapping of the geology for many miles outside the district as well as within it) that the primary regional stress is that which formed the San Andreas and other northwest-trending right-lateral faults, as described. This clockwise rotational stress was widespread, and must have been active at great depth. The counter-clockwise stress that formed the Garlock-Big Pine, Santa Ynez, and other east-trending left-lateral faults was either secondary to the more widespread clockwise one, or was acting independently, and possibly at an equally great depth. The compressive stress that formed the folds and thrust-faults may have been subsidiary to one or both these deep rotational stresses, and may have acted at comparatively shallow depths.

GEOMORPHOLOGY

Geologic factors controlling physiographic expression. The physiographic features that make up the landscape of this district as well as the adjacent ones are primarily the effect of compressive forces active during the Quaternary Period, and the effect of erosion of the features elevated by these forces. Throughout the district, the amount of relief is proportional to the amount of uplift. Within the map area the Santa Ynez and San Rafael Mountains have undergone the greatest amount of uplift and are consequently the highest areas. Areas that have undergone little or no uplift during the Quaternary Period are the alluviated valleys, such as upper Santa Ynez Valley and the level valleys of the coastal plain.

The details of the physiographic features elevated during the Quaternary Period have resulted from the drainage system that developed on these features, together with differential erosion of the tilted formations, each of which had a different resistance to weathering and erosion. Each formation exposed has been molded into a distinctive topography, described in the section under Stratigraphy. Most but not all the faults form characteristic local topography, such as notches across ridges, fault scarps, fault-line scarps, etc., as described under Structure.

Coastal Plain

Most, but not all, of the coastal plain has been slightly elevated during late Quaternary time, mostly by southward tilt. This has resulted in dissection of the late Pleistocene fanglomerate and older alluvium of the elevated portions. Parts of the coastal plain, such as the low, level alluviated parts of Goleta Valley, Santa Barbara-Montecito plain, and the Carpinteria Valley, were apparently never elevated during Quaternary time, but subsided, either in stages or continuously, as indicated by the thick accumulations of Quaternary sediments. They may still be subsiding, but if so are being filled with alluvium as rapidly as they subside.

Coastal terrace of Dos Pueblos area. The coastal area in the vicinity of Rancho Los Dos Pueblos west of Goleta Valley has risen since deposition of the older alluvium to form a coastal terrace that is now bounded along the sea shore by a steep cliff averaging about 80 feet in height. This terrace is divided into erosional remnants by streams draining southward across it that have graded their channels to the present sea level.

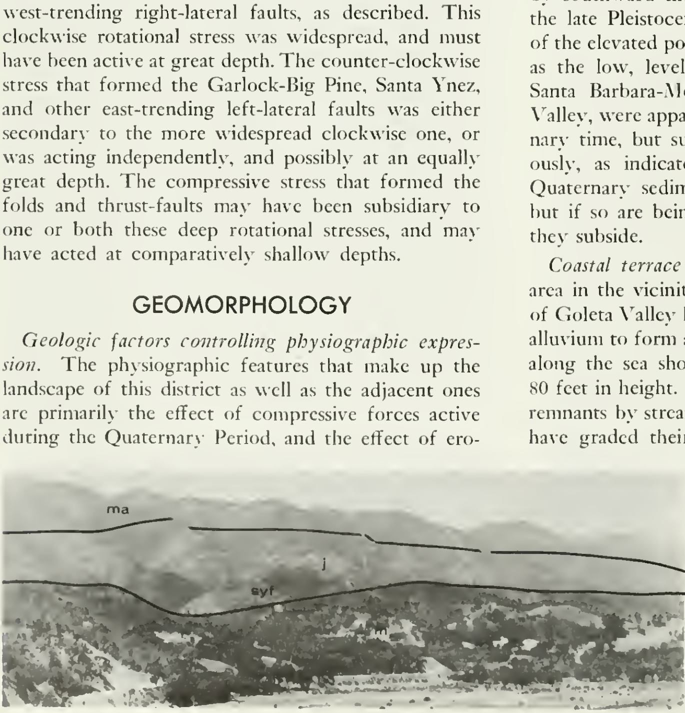


Photo 24. Santa Ynez Range viewed from northeast; Santa Ynez Peak near left, Santa Ynez River channel in foreground. Shows the following formations: Matilija Sandstone (ma); Jalama Formation (j); trace of Santa Ynez fault (syf); Miocene formations (m).

From the top of the sea cliff the terrace rises slightly landward to an average elevation of about 150 feet at its northern margin at the base of the foothills. This terrace is a beveled surface that is cut on tilted Miocene shales and overlain by a thin mantle of older alluvium. The surface was probably cut by waves when this area stood lower, as indicated by Pholad borings on the surface, and the presence of molluscan shells at the base of the older alluvium. At some places this terrace appears to be a single flat surface; at others, it is composed of several indistinct low benches. On the coastal area to the west, Upson (1951, pp. 424–435) recognized remnants of 17 wave-cut terraces between elevations of 5 and 200 feet. Within the mapped area, wave-cut terraces at about 60, 90, and 125 feet are represented in the coastal terrace.

The coastal terrace of Dos Pueblos area abuts rather sharply against the foothills to the north, along the margin of the older alluvium, as shown on the geologic map. These slopes rise abruptly from an elevation of about 150 feet along their base line to about 500 feet at the top of the hills. The slopes form crudely triangular facets between creek valleys and small canyons. The base line of these abrupt slopes was thought to be the scarp of a fault ("Naples fault") by Willis (1925, fault map) but geologic evidence of faulting here is lacking. More likely it marks the base of a former wave-cut cliff, as in the area to the west (Upson 1951, p. 419). This line of abrupt south-facing slopes extends eastward to the foothills about a mile north of Goleta, and if it is a wave-cut feature, then Goleta Valley was submerged under a shallow sea during the late Pleistocene.

Coastal mesa. The coastal mesa south of Goleta Valley was no doubt elevated slightly as a fault block since deposition of the older alluvium, which is now above the present sea level and is dissected. Along the present shore line this elevated area terminates along a steep cliff 30 to 100 feet high as does the coastal terrace westward from Goleta Valley. The western part of this elevated block is a low, flat mesa that stands at about the same elevation as the coastal terrace of Dos Pueblos area, and is cut through by one stream valley northwest of Coal Oil Point and another at Goleta Slough. From Goleta Slough this low mesa extends eastward to Punta Del Castillo and becomes a dissected coastal terrace exactly similar to that of Dos Pueblos area; on the north it abuts sharply against the steep southerly slopes of "La Mesa Hills," along a base line parallel to the present coast line and nearly a mile north of it. This base line is at an average elevation of about 150 feet, and is no doubt a former wave-cut shore line like that of the coastal terrace of Dos Pueblos area.

The coastal mesa area includes "La Mesa Hills" west of Santa Barbara, which rise to more than 500 feet in height, and are characterized by gently undulating summits and rather steep-sided canyons. These hills terminate on the northwest and northeast in a rather steep, abrupt slope that was once the scarp of the More Ranch and Mesa faults; this slope has, in most places, receded or been eroded back from its original position along the line of faulting.

Goleta Valley. Goleta Valley, or Goleta basin (Upson 1951, p. 9), a sunken area north of the elevated coastal mesa block, is now a low-lying plain filled with alluvium. It rises gradually westward through dissected older alluvium to the elevated coastal terrace. This plain also rises northeastward to the foothills along which dissected southwest-tilted fanglomerate is exposed.

Santa Barbara-Montecito plain. The city of Santa Barbara is on an alluviated coastal valley or plain, of which the low, level, southern part has been dropped, relative to the northern part, and filled with Recent alluvium. On the southeast it is open to the sea. As indicated by Upson (1951, p. 10) this alluvial plain is structurally continuous with that of Goleta Valley, although separated from it by low terrace remnants. Northeastward it rises to Mission Ridge and is much dissected. East of the mouth of Sycamore Canyon, however, and three-quarters of a mile from the present shore line, this alluviated coastal plain abuts against a steep, abrupt south slope, largely in fanglomerate, but partly in Monterey Shale. This slope rises from a base line of about 100 feet elevation to about 300 feet at the top. It is either a former wave-cut shore line, or is the scarp of a possible fault. Above this steep slope is a nearly flat terrace underlain by fanglomerate, abutting rather sharply against the hills of Miocene shale to the north, which may be another elevated wave-cut terrace.

The alluvial plain of Santa Barbara merges eastward into that of Montecito, which is a broad, undulating surface, somewhat dissected by streams, sloping gently from the base of the mountains southward to end as a low cliff at the sea shore.

Carpinteria Valley. Carpinteria Valley, or Carpinteria basin, as described by Upson (1951, p. 8), is a sunken area north of the elevated coastal fault block southeast of Carpinteria. Like Goleta Valley, it is a low-lying, almost level plain filled with alluvium. Its lowest part is partly submerged under brackish waters of the Carpinteria slough. This plain is open to the sea on the southwest. It rises gradually to the east, and

to the north it abuts rather sharply against the foothills along a rather straight base line that might be in part a wave-cut feature. If so, this plain was submerged under the sea sometime in the late Pleistocene.

The elevated coastal fault block south of the Carpinteria basin is a low mesa that rises to the east, and is bounded on the south by a sea cliff cut into Monterey Shale. The shale of this mesa was apparently beveled by waves, as marine molluscs are present at the base of the older alluvium, and there are Pholad borings on the surface of the underlying shale. At Carpinteria this wave-cut surface slopes westward to, or possibly below, the present sea level; but to the east it gradually rises, and south of Rincon Mountain, Ventura quadrangle, it is some 200 feet above sea level (Putnam 1942, p. 704).

Southern foothills of Santa Ynez Range. The foothills north of the coastal terrace of Dos Pueblos area and of Goleta Valley have rounded to nearly flat accordant summits at elevations of about 500 feet and are cut through by south-draining creeks that have eroded out small flood-plains. The nearly flat surfaces on the summits of these hills appear to be remnants of an old beveled surface cut mostly on the Sespe, Vaqueros, and Rincon Formations when the area was several hundred feet lower. This is attested by the presence of a thin veneer of older alluvium on several of the summits, as shown on the geologic map. This surface slopes very gently southward from the mountains, and probably once sloped seaward and into the coastal terrace and Goleta Valley, but the lowest part was destroyed, probably by wave action, as the sea eroded its way inland. The eroded surface of the summits of these hills probably correlates with the similar surface of low relief on the summits of "La Mesa Hills", and with that of the foothills north and northeast of Santa Barbara, including that of Mission Ridge, which slopes gently southward and is largely covered with fanglomerate.

Santa Ynez Mountains

The Santa Ynez Range is a prominent, straight, single-crested mountain ridge that extends unbroken for a distance of some 50 miles from Gaviota Canyon, Gaviota quadrangle, eastward to Matilija Canyon, Ventura quadrangle. The physiographic expression of this range quite accurately reflects its geologic structure. With the exception of the San Marcos Pass area, this range rises from the foothills northward to a ridge with an even skyline at an average elevation of about 3500 feet, that is about 6 miles north of the coast line; then drops off abruptly on the north to the Santa Ynez fault at its base, about 1½ miles north of the crest. This high crest tapers down to a low point of 2230 feet at San Marcos Pass.

Southwest of San Marcos Pass the crest has a rounded summit that tapers down toward the east. This is the physiographic expression of the eastward-plunging Brush Peak anticline in resistant "Coldwater" Sandstone. On the north flank of the range north of San Marcos Pass, Los Laureles Canyon follows the northwest-trending axis of the syncline of that name; Paradise Canyon to the northeast partly follows the axis of the Painted Cave syncline; and the intervening northwest-trending ridge is eroded from the intervening anticline.

As the Santa Ynez Range, with the exception of the San Marcos Pass area, is differentially eroded from formations that generally dip south, the crest is essentially a strike ridge; the north flank is a steep escarpment slope with ledges dipping into it, and the south flank is characterized by dip slopes. On the south flank of the eastern sector of the range, the formations, where they are overturned southward, are differentially eroded to step-like topography.

Thick sandstone units such as the Matilija and "Coldwater" tend to form ridges; but these sandstone units do not everywhere form the crest of the range. Indeed, eastward from La Cumbre Peak, the crest is eroded from weakly resistant shaly strata and thin sandstone interbeds of the Juncal Formation, rather than the resistant Matilija Sandstone. The position of the crest of the range is not necessarily determined by the position of exposures of resistant thick sandstone units; instead, it is probably dependent on the Santa Ynez fault, some 1½ miles to the north, along which the range is being elevated.

The drainage system of this straight single-crested range is simple. On both flanks, streams drain directly away from the crest, and across the strike of the exposed strata where the structure of the range is homoclinal. The north flank is drained by short, steep canyons. In the eastern sector most of these are partially deflected to the west at the Santa Ynez fault. The south flank of the range is drained by comparatively long canyons, most of which have reached grade in their lower courses and have formed small flood plains.

Santa Ynez River Area

Santa Ynez River. The Santa Ynez River cuts a slightly meandering course through an area of hills. Despite its meandering, the river drains consistently north of west, parallel to the Santa Ynez Range to the south, generally along strike of the exposed formations. The upper course of the river is eroded along or near the Santa Ynez and Juncal Camp faults, then follows the strike of weakly resistant Espada shale just north

Photo 25. City of Santa Barbara and Santa Ynez Range viewed from southwest at Pockards Hill. Eocene formations exposed in Santa Ynez Range; Miocene formations in foothills.

of the Little Pine fault. It crosses this fault at the Santa Barbara reservoir, and below that point practically its entire course is eroded through Monterey Shale, generally along the strike. The river has reached grade and is now in the process of forming a small flood plain, especially along its course below the mouth of Redrock Canyon.

It is noteworthy that near Juncal Camp the Santa Ynez River is only 5 miles from the sea, yet drains some 50 miles west before entering it. It is apparent that the Santa Ynez River, into which are gathered several large creeks that drain the San Rafael Mountains to the north, owes its position to uplift of the Santa Ynez Range, which acts as a barrier to southwestward drainage from the much more extensive mountain area to the northeast. This condition indicates that the Santa Ynez and San Rafael Mountains were elevated contemporaneously.

Area in vicinity of Santa Ynez River. The area between the Santa Ynez fault and the Santa Ynez River from Juncal Camp to Los Prietos Ranger Station is characterized by short strike-ridges trending north of west, between narrow steep-walled canyons that drain northward to the Santa Ynez River. The foothills between the western sector of the Santa Ynez Range and the Santa Ynez River are low and rounded, and partly buried or capped by fanglomerate. These foothills are transected by narrow steep-walled northward-draining canyons.

The hills north of the Santa Ynez River and westward from the mouth of Redrock Canyon are in places quite rugged, especially in exposures of soft but coherent conglomerates and sandstones of the north-dipping Paso Robles Formation that are eroded to badlands. Northward from these badland hills the terrain becomes progressively less rugged toward the axis of Los Alamos syncline. In the area west of lower Cachuma Canyon the surface of deposition of the older alluvium that filled upper Santa Ynez Valley is still preserved from erosion, though warped and partly dissected.

San Rafael Mountains

The small southern part of the San Rafael Mountains within the map area is mountainous and semi-mountainous, being differentially eroded from greatly deformed formations of varying resistance. In these mountains the pattern of ridges and canyons is in part controlled by the geologic structure of the underlying formations. In the western part of this area the highest ridges are those with rounded summits eroded from thin-bedded but hard siliceous Monterey Shale, such as Little Pine Mountain, Loma Alta, and the high hills north of the Santa Ynez River; also the high, sharp

strike ridge of Camuesa Peak, eroded from hard sandstones within shales of the Espada Formation. Of these the strike ridges of Little Pine Mountain and Camuesa Peak are much the highest because of uplift on the Little Pine fault. The large area underlain by weakly resistant, predominantly shaly strata of Cretaceous age, between Camuesa and Agua Caliente Canyons and northeast of the Little Pine fault, is reduced to comparatively low relief in which the thin sandstone layers stand out as low but sharp parallel ridges.

Eastward from Agua Caliente Canyon the terrain becomes progressively more rugged and mountainous. The thick resistant interbeds of sandstone in the less resistant shale of the upper Cretaceous and Eocene formations crop out as prominent ledges, dip slopes and strike ridges that rise eastward to heights greater than that of the crest of the Santa Ynez Range.

Camuesa, Indian, Mono and Agua Caliente creeks are the major stream channels through which run-off waters from the higher San Rafael Mountains to the north drain southward into the Santa Ynez River. All have cut small flood-plains in their lower courses where they pass through weakly resistant Cretaceous shale.

Geomorphic History

The physiographic features within the district evolved from episodes during the entire geologic history of the region, but mainly from those during the Quaternary. The district mapped has probably been through at least two cycles of erosion during the Quaternary, the same two as in the region to the west (Dibblee, 1950, pp. 19–20), and in the Ventura region (Putnam, 1942, p. 784). The first cycle was an episode in middle (?) or late Pleistocene time, following deposition of the Paso Robles, Santa Barbara, and Casitas Formations, and ending with deposition of the fanglomerate and older alluvium. The second or present cycle began in late Quaternary time, and includes deposition of Recent alluvium.

In the early stage of the middle (?) and late Pleistocene episode, the compressive forces that elevated the mountain areas must have intensified, causing increased movement on the major faults and the instigation of new ones. There was further compression of folds formed during the preceding episode, and in the alluviated plain between the two mountain ranges, and on the coastal plain, new structures that involved formations deposited during the preceding early Pleistocene episode were formed. This intensified disturbance resulted in the rise of the two mountain ranges to heights probably greater than their present heights, formation of the present foothills, and the establishment of the present drainage system. During the early stage of this episode, erosion of the uplifted areas, especially of the mountain areas, must have been severe. In the early stage most, if not all, of the eroded detritus must have been carried away; but in a later, probably climactic stage, coarse detritus was deposited as fanglomerate on the eroded surface of the base of the Santa Ynez mountains to form large alluvial fans. The finer detritus was washed farther out into the valley areas and deposited as older alluvium. The late and final stage of this episode must have been one of relative quiescence as the mountains were eroded to comparatively low relief, or prabably to the late maturity stage of the first erosion cycle; the foothill and "Mesa Hills" areas were probably reduced to the old age stage of this cycle; and the sea must have advanced inland by wave erosion to a shore line from three-quarters of a mile to nearly 3 miles north of the present shore line.

In late Pleistocene time, the compressive forces previously active uplifted to their present heights the areas already elevated during the previous episode. The mountain ridges were uplifted the most—perhaps as much as 1,000, or possibly 2,000, feet above their previous heights.

In the Santa Ynez Valley area this disturbance involved the older alluvium which became warped slightly by renewed compression of the Los Alamos syncline. The renewed uplift of the Santa Ynez Mountains involved the fanglomerate which became elevated by outward tilt, and in places south of the mountains was broken by faulting. As a result of this renewed uplift both the fanglomerate and the older alluvium have since been much dissected. This uplift involved the coastal plain, causing withdrawal of the seat to its present shore line, but uplift of the coastal area was unequal, as parts of it, such as the low level parts of Goleta and Carpinteria basins failed to rise or even continued to subside, while the coastal fault blocks to the south rose, as during the preceding episode.

The late Pleistocene uplift caused all streams in the affected areas to deepen their channels, probably by successive stages, as indicated by the presence of terrace gravels at several levels along the Santa Ynez River and its tributaries. Erosion that accompanied this recurrent uplift progressed to the middle maturity stage of the present erosion cycle in the mountain areas, as indicated by V-shaped canyons and sharp ridges. It has practically destroyed the elevated middle (?) Pleistocene erosion surface, although remnants of it may be represented by the subdued topography on the summit of Little Pine Mountain and Loma Alta, the even crest line of the Santa Ynez Range, and the subdued topography at the summit in the San Marcos Pass area. In the foothill areas of both sides of the Santa Ynez Range this earlier subdued erosion surface

is locally preserved, but it and the old alluvial fans that partly bury it are now but remnants, having been severely dissected by the deepened stream channels from the mountains.

The coastal part of Dos Pueblos area, together with the coastal blocks south of the Goleta and Carpinteria basins, were re-elevated from heights of 30 to 200 feet to their present heights contemporaneously with the recurrent late Pleistocene uplift of the mountain areas. This uplift resulted in the present coastal terraces and mesas and their bounding cliffs along the present seashore, and the deepening of stream-channels that transect these re-elevated coastal areas as they graded their channels to the present sea level.

For detailed description of late Pleistocene and Recent episodes along the Santa Barbara coastal area, the reader is referred to two papers by Upson (1949, pp. 94–115; 1951, pp. 415–466).

SUMMARY OF GEOLOGIC HISTORY

1. Late Jurassic(?). Regional subsidence and deposition of Franciscan sandstone, shale, and chert under sea; intrusions of basalt and peridotite, later altered to greenstone and serpentine, respectively.

2. Early and Late Cretaceous. Regional subsidence and depostion of shale and some sandstone of Espada Formation in shallow sea.

3. Late Cretaceous. Regional subsidence and deposition of shale, sandstone, and conglomerate of Jalama Formation in shallow sea.

4. Paleocene(?). Uplift and emergence of area now the Santa Ynez Valley and southwestern part of San Rafael Mountains, with deformation and erosion. This was "San Rafael Uplift" of Reed and Hollister (1936).

5. Early to middle(?) Eocene. Marine transgression from southeast over "San Rafael Uplift", and deposition of Sierra Blanca Limestone in shallow transgressing sea.

6. Middle(?) and late Eocene. Regional subsidence and deposition of shale and sandstone of Juncal, Matilija, Cozy Dell, Sacate, and "Coldwater" Formations under sea.

7. Oligocene. Renewed rise and emergence of "San Rafael Uplift," or area north of present Santa Ynez Range, with deformation and uplift to highland of moderate to high relief, erosion; regression of sea in area that is now the Santa Ynez Range and the coastal plain, with deposition of littoral sandstone of uppermost "Coldwater" and of Gaviota Formation in westward-regressing sea; accompanied and followed by deposition of stream-land conglomerate, sandstone, and red claystone of Sespe Formation on level plain as this area continued to subside.

8. Early Miocene. Continued erosion of "San Rafael Uplift", which was gradually reduced to low relief; transgression of sea over area now the Santa Ynez Range and coastal plain, with deposition of littoral Vaqueros Sandstone in northward-transgressing sea; followed by deposition of Rincon Shale as area subsided and sea deepened.

9. Middle and late Miocene. Subsidence of entire area under a widespread sea, and deposition of calcareous, argillaceous, and siliceous sediments of Monterey Shale; abundant organic life.

10. Late Miocene. Continued subsidence, but with possible initial submarine arching of area now the site of the Santa Ynez Range; deposition of diatomite of Sisquoc Formation and of Tequepis Sandstone north of this submarine(?) arch; of diatomaceous siltstone of Sisquoc Formation south of it.

11. Early or middle Pliocene. Regional emergence, probably affecting entire district; initial rise of San Rafael and Santa Ynez Mountains and probably coastal area, involving strong deformation, erosion; area now the Santa Ynez Valley area probably emergent but not deformed.

12. Late Pliocene. Probable continued rise and erosion of San Rafael and Santa Ynez Mountain areas; slight subsidence of site of Santa Ynez Valley area and marine transgression from west into it, with deposition of Careaga Sandstone in shallow embayment; partial marine transgression from south onto coastal plain, with deposition of "Pico" siltstone.

13. Early Pleistocene. Continued rise and severe erosion of San Rafael and Santa Ynez Mountains; subsidence of Santa Ynez Valley area; rapid deposition of stream-laid alluvial sediments of Paso Robles Formation, forcing back marine embayment; partial and unequal subsidence of coastal plain with deposition of sands of Santa Barbara Formation on submerged shelf in Goleta-Santa Barbara area, and of stream-laid alluvial sediments of Casitas Formation on coastal plain in Carpinteria area.

14. Middle(?) and late Pleistocene. Continued and accentuated rise of San Rafael and Santa Ynez Mountains, with strong deformation and severe erosion; Santa Ynez Valley and much of coastal plain involved in this diastrophism; mountains probably of high relief during early stage of this episode, reduced to lower relief in late stage; deposition of torrential fanglomerate as alluvial fans at base of Santa Ynez Range, older alluvium on eroded surface of Santa Ynez Valley area and of coastal plain in late stage of this episode, development of present drainage system.

15. Late Pleistocene. Recurrent rise of San Rafael and Santa Ynez Mountains to present high relief; also slight recurrent rise of Santa Ynez Valley and of coastal plain (with exception of parts of Goleta basin, Santa Barbara—Montecito plain and Carpinteria basin) to present topography; renewed erosion with deepening of stream-channels of present drainage system and dissection of alluvial fans and older alluvium.

16. Recent. Continuation of last episode, with deposition of alluvium in level valley areas and on flood-plains of stream-channels; slight rise of sea level.

MINERAL RESOURCES

Asphaltum, Petroleum, and Gas

Petroliferous seeps. Natural seeps of tar, oil, and gas are common in the coastal area south of the Santa Ynez Range, but none are known to occur in the area north of it. Most of these seeps issue from or near outcrops of Monterey Shale, on or near the sea cliffs. Several are found in younger formations on the sea cliffs, and several others issue from the Eocene Cozy Dell Shale in th Santa Ynez Mountains north of Carpinteria Valley. Nearly all these bituminous seeps issue from these formations where they dip steeply southward, or in places where they are overturned southward. From these upturned strata the bituminous seeps have issued for many thousands of years and bitumin has probably migrated from great distances up dip from beds far down under the Santa Barbara channel; because there are no structural barriers to prevent their upward migration, they have reached the surface and escaped. Only in a few places, where structural traps were formed, the upward migrating hydrocarbons have been caught and held to form the oil and gas fields described in subsequent paragraphs.

The bituminous seeps in the Monterey Shale and younger formations of the coastal bluffs are of asphaltic tar or heavy black asphalt-base oil that are probably indigenous to the Monterey Shale. Most of these issue from fracture zones of brittle siliceous shale; they are most prolific along the shale cliffs southeast of Carpinteria. Others occur along the Monterey Shale cliffs of "the Mesa", west to Goleta Slough, and in the vicinity of Elwood oil field. Seeps of black tarry oil issue from the Casitas Formation at and near the Summerland beach.

Minor seeps of gas, chiefly methane, issue from the Monterey Shale in the vicinity of the tar seeps at several places along the beaches and at Goleta Slough, and can be seen bubbling through the water. Prolific gas seeps and some oil seeps are known about a mile off shore from Coal Oil Point.

Seeps from the Cozy Dell Shale in Toro and Oil canyons are of tarry black oil that is probably indigenous to this formation. Several other seeps of this kind of oil occur in the "Coldwater" Sandstone south of the Arroyo Parida fault just beyond the east border of the map area.

Asphaltum. Besides the tar seeps along the sea cliffs there are two deposits of tar, or asphaltum—one at Carpinteria and one at More's landing at Goleta gas field. Tar from these deposits, as well as that from the seeps, was used by the Chumash Indians for caulking canoes, waterproofing baskets, as adhesive material, and for many other purposes.

The Carpinteria deposit, known as the Carpinteria tar pits, is located near the sea cliff half a mile southeast of Carpinteria. Asphalt from this deposit was quarried as early as 1857 when Charles Morrell, a druggist from San Francisco, erected a distilling plant nearby and produced illuminants, but without commercial success. The pits are roughly 25 feet deep and cover several acres. The asphalt is at the base of flat-lying older alluvium, and impregnates several feet of the basal conglomerate and some of the overlying sand. There are several active tar seeps, and these no doubt issue from vertical or steeply dipping beds of Monterey Shale that lie below the older alluvium and are exposed on the adjacent sea cliff.

The deposit of asphalt near More's landing is just southeast of the Goleta gas field. This deposit is at the base of the "Pico" Formation in the form of heavy saturation of asphalt in the basal 20 feet of fine sandstone of this formation, which here dips about 25° east and unconformably overlies Monterey Shale which dips about 45° southeast. The asphalt accumulated from the large active tar seeps that issue from the unconformable contact of these two formations.

Oil and gas field development. Within the mapped district are several oil fields and one gas field, all on or near the coast. Only one of the oil fields is a major field that is still producing; the others were minor fields and are now abandoned. From west to east, the fields are Goleta (or Tecolote Canyon), Elwood, Goleta gas field, Mesa, Summerland, and Toro Canyon.

The Summerland and Toro Canyon fields were discovered in the 1890's from oil seeps. The Goleta and Elwood oil fields were discovered in 1927 and 1928, respectively, on the basis of surface geology. For many years after the discovery of those fields in which oil and gas were found in the Sespe and Vaqueros sands, the district was intensively prospected; test holes were drilled to these sands on all favorable and possibly favorable structures, in both the coastal and Santa Ynez River areas. The exploratory holes resulted in the almost immediate discovery of La Goleta gas field and the Mesa field, and a small production from below the old Summerland shallow field. All other test wells were unsuccessful, although many encountered showings; exploratory drilling has gradually dwindled.

In recent years, mostly since 1945, several major oil companies have been prospecting the offshore area through geologic and geophysical work, and from several deep test-holes slant-drilled from shore between Coal Oil and Goleta points. While the operators released no information on their offshore exploratory activities, oil was reportedly discovered in at least two of these deep slant-drilled test holes. Production was soon exhausted. In 1956 a major oil field was discov-

ered in a test hole drilled from a barge 1½ miles offshore from Summerland. This field is now being developed.

Goleta or Tecolote Canyon oil field. In 1926 the Miley Oil Company Goleta No. 1 well was drilled to a depth of 5,664 feet, to test the top of the "Coldwater" Sandstone on the Tecolote anticline in Tecolote Canyon. This sandstone was found to be tight and unproductive, but two oil-saturated zones were found in the Sespe Formation, one at a depth of 613 feet, the other at 1,527 feet. Goleta No. 2 was drilled and completed in 1927 in the lower zone for 450 barrels per day of 44° gravity paraffin-base oil. Many other wells were drilled nearby, and one of these (Santa Barbara Oil Co.—Hollister No. 2) was completed for 1,040 barrels per day. Only the wells on the structurally highest part of this anticline in Tecolote and Winchester Canyons were productive, and these were soon depleted with the rapid encroachment of water. The field was abandoned in 1928, thirteen months after its discovery.

Elwood oil field. In 1928 the Elwood oil field was discovered on completion of the Barnsdall and Rio Grande Luton Bell No. 1 well at 3,208 feet, for a daily flow of 1,755 barrels of 38° gravity clean oil and an estimated 750,000 cubic feet of gas per day, from the upper 34 feet of the Vaqueros Sandstone. Orderly development progressed rapidly, both on shore and on piers off shore, and peak production was reached in 1930, with 33 wells accounting for 6 percent of all California production of that year. Early completions commonly flowed about 2,500 barrels daily of clean oil, but rapid water encroachment and decrease of pressure necessitated the early use of gas lift and pumping, and most of the wells have declined to a few tens of barrels of oil per day. As of 1946, this field has produced 77,614,000 barrels of 32° to 38° gravity oil from a proven area of 520 acres. Since 1944 slant drilling from shore by the Signal Oil Company has resulted in an extension of the field to the west offshore, which should materially add to the reserves.

The subsurface structure of the Elwood anticline, in contrast to its strongly compressed structure at the surface, is that of a comparatively gently folded domed arch with eastward and westward closure of several hundred feet from a high point just off shore from the mouth of Bell Canyon. This anticlinal arch is supposedly broken on its north flank by the west end of the More Ranch fault. The western offshore extension of the Elwood field may be on a separate rise of the Elwood anticline, but no geologic information on this structure has been released.

The Vaqueros Sandstone is the major productive zone of the Elwood field, at depths from 3,050 to 3,550 feet. Prior to 1931 all production was from this zone. During that year a small production of 23° gravity oil and some gas was made from eight wells in fractured Rincon shale.

Several wells drilled into the Sespe Formation encountered in it three oil and gas zones. The upper Sespe zone, near the top of the Sespe Formation, flowed 1,059 barrels of 36° gravity oil and 546,000 cubic feet of gas daily from its discovery well in 1935. This zone is about 170 feet thick and is productive in 17 wells. The middle Sespe zone, 850 feet below the top of the Sespe Formation, was productive in only one well, in which it flowed initially at a rate of 2,389 barrels of 42° gravity oil and 2,000,000 cubic feet of gas daily from 60 feet of sand. The lower Sespe zone, about 1,900 feet below the top of the Sespe Formation, was discovered in 1936 and was productive in only two wells, of which the first produced initially 68 barrels of 33.5° gravity oil and 602,000 cubic feet of gas per day at depths from 5,980 to 6,271 feet.

The geology of the Elwood oil field is described by Dolman (1931, p. 5–13), and Hill (1938, pp. 380–383).

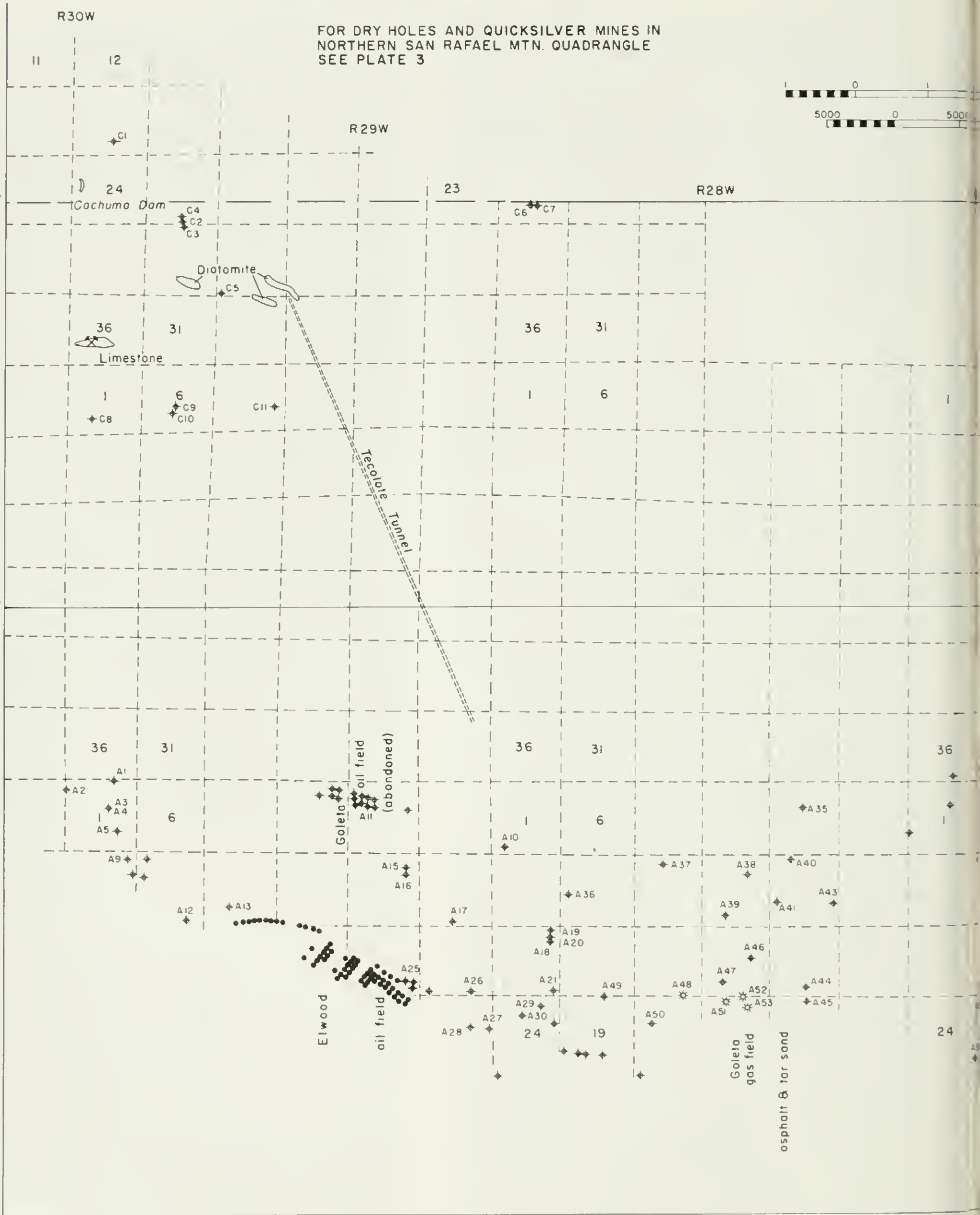
Goleta gas field. In 1929 General Petroleum Company discovered Goleta gas field with its More No. 1 well, which flowed gas at an estimated rate of 60 million cubic feet per day from the Vaqueros Sandstone topped at 4,533 feet. Five other gas wells were subsequently completed from this sand. Some of the largest gas producers in the state are in this field, the Pacific Lighting Corp., Miller No. 1, having produced at the rate of 145,100,000 cubic feet per day. The limits of the field have been defined by several dry holes.

As of 1937, Goleta gas field has produced 14,000,000,000 cubic feet of gas from a proved area of about 250 acres. A small amount of condensate oil of about 60° gravity was produced with the gas.

The structure of Goleta gas field is a small closed anticlinal dome in the Miocene formations on the south side of the More Ranch fault. The axis trends slightly north of west, somewhat diagonal to the fault, as indicated from surface outcrops in the Monterey Shale. At the structurally highest part of this fold the top of the Vaqueros Sandstone is about 4,000 feet below sea level; the formation yielded gas down to about 4,400 feet below sea level. Water lies directly below the gas zone with no intervening oil zone. One well was drilled through the Sespe Formation and topped the "Coldwater" Sandstone at 6,700 feet; although sands in the upper part of the Sespe had numerous oil "shows", none yielded commercial production.

The geology of Goleta gas field was described by Swayze (1938, pp. 384–385).

Mesa oil field. The Mesa oil field was discovered in 1929 with small production of oil in the Vaqueros


FOR DRY HOLES AND QUICKSILVER MINES IN
NORTHERN SAN RAFAEL MTN. QUADRANGLE
SEE PLATE 3
R30W
R29W
R28W
34°35'
34°30'
Cachuma Dam
Diatomite
Limestone
Tecolote Tunnel
Goleta oil field (abandoned)
Elwood oil field
Goleta gas field
asphalt & tar sand

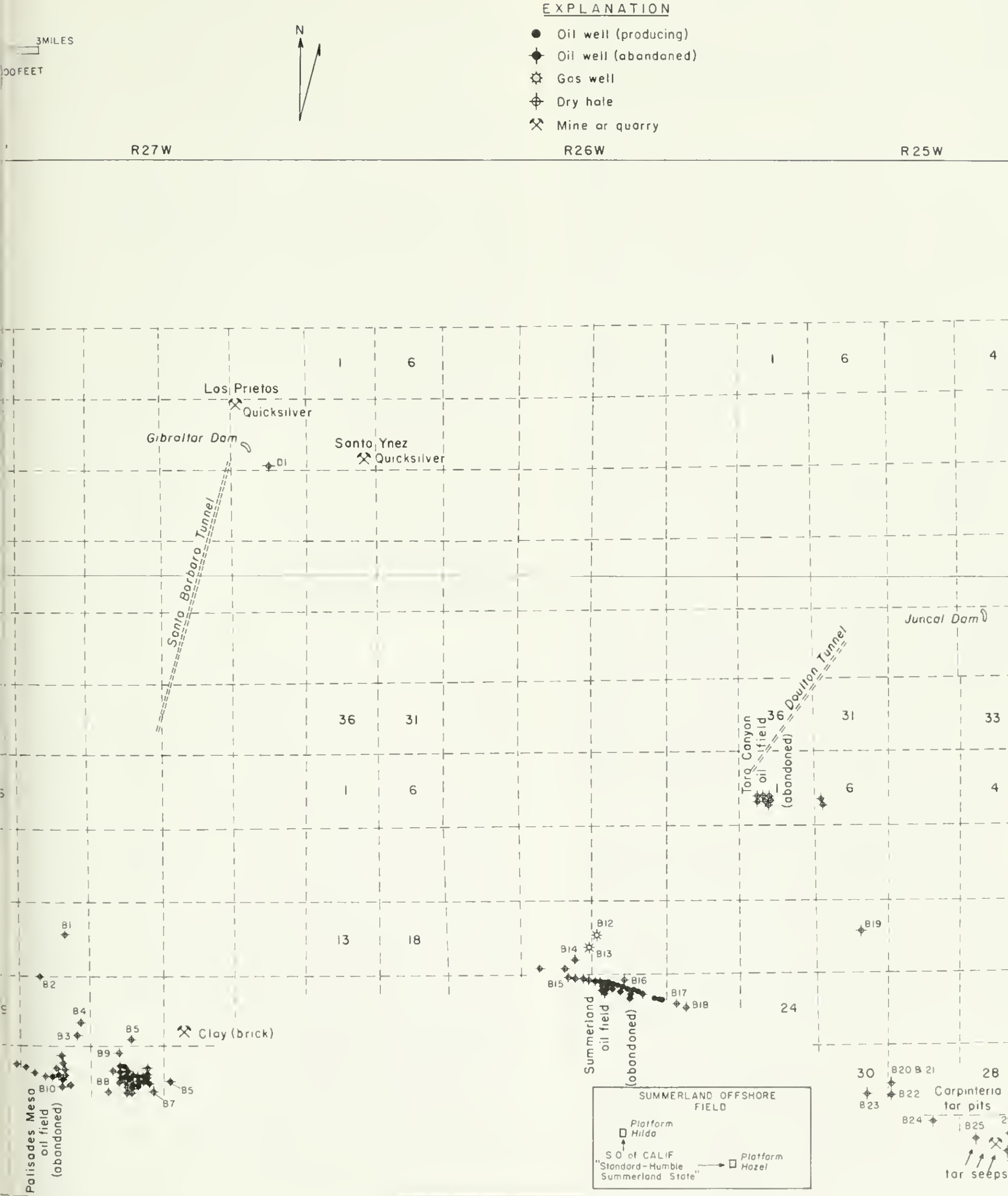


Figure 10. Economic map of central Santa Ynez Mountains and vicinity, Santa Barbara County, California.

Sandstone. Numerous wells were drilled on town lots. Initial production in some wells was as much as 200 barrels daily, but gradually dwindled to only a few barrels a day. The oil had given way to water in all wells by 1950, and the field is now abandoned. This field produced about 3,667,000 barrels of 14° to 19° gravity oil from 165 acres.

Wells of the Mesa oil field topped the Vaqueros Sandstone at depths from 1,950 feet to 2,050 feet and produced from the interval 1,950 to 2,100 feet. One well was drilled 2,000 feet into the underlying Sespe Formation but found no oil in it. The productive area of the Vaqueros Sandstone is a nearly flat-lying structural terrace with southerly dips both north and south of the field. The flat-lying part of the terrace is bounded on the north and northeast by a fault along which there has been about 200 feet maximum relative upward displacement of the southern block. This fault forms the northern and northeastern limits of the productive area. There seems to be no structural closure on the northwest. The subsurface structure of this field is not indicated from surface outcrops, as the Miocene shales exposed on the sea cliffs dip south at moderately steep angles. Details of the geology of the field were described by Dolman (1938, pp. 5–14).

Palisades Mesa oil field. At about the same time the Mesa oil field was discovered in 1929, a well was drilled nearly a mile west that encountered a little heavy oil in the Vaqueros Sandstone at about 2,000 feet. Hectic town-lot drilling immediately followed, and the little oil encountered in a few wells was soon depleted.

The structure of this area, like that of the Mesa oil field, is a small flay-lying terrace with southerly dips to the north and south. There is no apparent structural closure on the north, although there may be one or two minor faults.

Summerland oil field. The Summerland field is one of the oldest oil fields in the State, having been discovered in 1894 from oil seeps on the beach. It was developed mainly between that year and 1910. In the early 1900's there were more than 300 wells producing an average of about five barrels a day of 14° to 22° gravity oil from one or more sands in the Casitas Formation ("Fernando" of Arnold, 1907), from depths of 100 to 600 feet. The shallow productive wells of this field were drilled along and near the beach, on wooden piers. After 1910 oil production from this shallow field gradually declined as water encroached, and by 1928 all but one or two wells at the northwest end of the field were abandoned. In 1928 several deeper wells were drilled that resulted in a small production (less than 200 barrels daily) of 16° gravity oil from the Vaqueros Sandstone at the northwest end of the field; but these, too, gradually declined to uneconomic rates, and are now suspended.

This field has produced 3,180,000 barrels of oil from a productive area of 180 acres. It is now practically abandoned and the wooden piers used for off-shore developments have been destroyed by high waves.

The structure of the Casitas Formation or "Fernando" of Arnold (1907), of the Summerland oil field, is partly exposed along the sea cliffs, and the subsurface structure, as interpreted from well logs is described in detail by Arnold (1907, pp. 39–56). The sea cliffs reveal at least two anticlinal folds, one at each end of the field. The Loon Point anticline is at the southeast end and has an axis trending north of west, practically along the beach. Near Loon Point this fold plunges southeastward and is partly broken by a small south-dipping thrust fault. To the northwest, this fold appears to flatten and die out.

The northwestern anticline is a sharp fold with an axis trending northwest under the hill west of Summerland. As seen on the sea cliffs, it has a broad southwest flank dipping 35° to 50°, and a narrow northeast flank dipping 85° near the axis, flattening rapidly northeastward. As contoured by Arnold (1907, pl. VI) this fold plunges southeastward under the sea and dies out into a south-dipping homocline off shore.

The main productive sand of the Casitas Formation is from 100 to 200 feet above the base. At the beach of Summerland this sand lies a few feet below the surface and lenses out to the north. Southward down dip it goes deeper, and thickens to as much as 100 feet. Down dip to the south are several other thinner sands —at least two below the main sand and three above it that have yielded oil. Most of these sands lens out up dip to the north, and all are within "blue clay" as indicated on drillers' logs. Most of the oil was obtained at depths between 100 and 400 feet.

The structure of the Miocene formations of the Summerland field, as indicated from logs of deeper wells drilled since 1928, is not clearly understood; but it is probably a much-faulted anticline. The wells pass from the Casitas-Santa Barbara strata into the Rincon Shale, then into the Vaqueros Sandstone and Sespe Formation. The Getty Becker well, drilled in the town of Summerland at Temple Street, and just north of the present highway, topped gray Vaqueros Sandstone at 2,250 feet, and penetrated the Sespe Formation from 2,713 feet to bottom at 5,041 feet. Another well drilled on the beach about 1,200 feet southwest of this well entered tight Vaqueros Sandstone at 700 feet and Sespe from 1,160 to bottom at 1,174 feet. At the base of the high sea cliff at the northwest end of the field, the Lincoln Drilling Co.-Williams No. 1 well topped the Vaqueros Sandstone at 1,125 feet and bottomed at 1,417 feet. This well produced initially about 300 barrels daily of 16° gravity oil from the Vaqueros

Sandstone. Several other wells were drilled nearby into this sand, but obtained only a small production that declined rapidly. The northernmost and structurally highest of these wells topped the Vaqueros Sandstone at 875 feet.

A well drilled on the hill a third of a mile north of Summerland found the Vaqueros dry, but obtained a small gas production from sands between 3,590 and 4,300 feet in the Sespe Formation.

Toro Canyon field. In Toro Canyon in the Santa Ynez Mountains 3 miles north of Summerland, several shallow wells were drilled in the 1890's at and near oil seeps in vertical and overturned beds of the upper part of the Cozy Dell Shale. As indicated by Arnold (1907, p. 55) the Santa Barbara Oil Co. drilled two wells to 500 feet and 600 feet respectively in steeply overturned (Cozy Dell) shale in the vicinity of the tar seeps of this canyon. They produced a small amount of oil and much gas. Three quarters of a mile west of these wells, the Occidental Mining and Petroleum Company drilled seven wells to depths of from 200 to 1,100 feet. Four of these produced a few barrels each of black 17° gravity oil per day on pump. One is said to have produced 5,000 barrels. The other three wells were dry. Besides these, a tunnel was dug 511 feet N. 10° E. into the mountains, which yielded a little oil. All of these old wells are now abandoned.

Quicksilver

The following information on the quicksilver mines near Gibraltar Dam is taken from reports by Bradley (1918, pp. 150–152), Tucker (1925, pp. 543–544), and Ransome and Kellogg (1939, p. 450).

In 1860 quicksilver ore was discovered in the narrow serpentine belt adjacent to the Little Pine fault, near the present site of Gibraltar Dam. The ore was not worked extensively until 1874, when the price of quicksilver rose; then a large furnace was erected on the Santa Ynez River below the mine. Los Prietos mines, as the workings were known, consisted of several groups of claims along 3 miles of the mineralized serpentine belt. Ore from these claims was mined and milled until 1877, but then operations ceased because of a decline in the price of quicksilver and prolonged litigation over title to the property. Most of the workings caved, and the mill fell to ruins. In 1916, when the price of mercury rose as the result of World War I, the mines were taken over by the Los Prietos Mining Company of Los Angeles, which erected a 12-pipe retort mill and made a small production from 1916 to 1918. Thereafter, the mines were again idle until 1930. A small production of quicksilver was recorded in 1930–1933, 1935, and 1938–39.

Los Prietos mines are on two groups of claims: the Juniper claims, or the Snow workings, on which are located Los Prietos mine proper, on a hill half a mile north of Gibraltar Dam; and the Santa Ynez group of claims, or the Milburn-McAvoy workings, on a hill 1½ miles east of the Dam and south of the Santa Barbara Reservoir.

On the Juniper claims the principal workings were one large and several small open cuts extending for a length of 450 feet along the hanging-wall portion of the north-dipping "vein", from which three short tunnels were driven into the "vein".

On the Santa Ynez group of claims the principal workings were a tunnel driven 45 feet eastward along the "vein" from the west slope of the hill several hundred feet above the level of the river; 50 feet above is another tunnel driven 200 feet eastward along the footwall portion of the "vein".

The Mercur claim was located in 1916 at the juncture of Camuesa Creek with the Santa Ynez River. It was owned by F. E. Wilson and O. W. Boseke. Development consisted of a 30-foot shaft sunk on the "vein", then drifted 30 feet. A small concentrating mill of 6 tons capacity was built that year and one flask (75 lbs) of quicksilver was reported to have been produced.

The quicksilver ore along the 3-mile-long serpentine belt of the Santa Barbara reservoir area is cinnabar, the red sulphide of mercury. It is finely and irregularly disseminated along the "vein", which is a zone of sheared and brecciated material along the contact of serpentine rock and the hard olive-green sandstone and shale of the overlying Espada Formation to the north. Much of the serpentine of this belt is altered or partly altered to yellow and brown hard silica-carbonate rock that forms bold outcrops. The "vein" material or ore is from 20 to 100 feet wide and dips from 60° to 75° N. In all the mines the ore is generally of low grade averaging about 0.25 percent cinnabar; but a few rich pockets or shoots that were encountered contained as much as 13 percent cinnabar. The depth to which the ore extends has not been determined, but it must extend at least several hundred feet below the surface. At the mouth of Camuesa Creek some ore may be covered by the water of the Santa Barbara reservoir.

Limestone

A deposit of limestone possibly suitable for use in cement occurs on the ridge between Hilton and Tequepis Canyons, 2 miles north of Santa Ynez Peak. This limestone, which forms the basal part of the Monterey Shale, is about 200 feet in maximum thickness, dips gently to the south, and is traceable along strike for half a mile. It is cut off on the south by

the northern branch of the Santa Ynez fault where the rock forms a shear cliff about 200 feet high. The limestone has a thin overburden of cherty siliceous shale on top.

In 1952 much of this limestone was quarried in large fragments that were used in construction of the Cachuma rock dam.

The Sierra Blanca Limestone, where not too sandy, is of potential use for cement manufacture. In most places it is too thin and impure, except on Sierra Blanca Ridge at the northern border of Little Pine Mountain quadrangle where it is as much as 235 feet thick and free from overburden.

Clay

Low-grade clays suitable for manufacture of brick and tile are present in the Sespe Formation. The best clays are weathered red clays in the upper part of the formation, and are interbedded with sandstone.

The Santa Barbara Builders Supply Company owns two brick and tile plants, one in Santa Barbara, the other east of Montecito. The Santa Barbara plant is at the west end of Montecito Street at the foot of the bluff of "the Mesa", half a mile from the beach. Weathered yellow sandy clay of the Sespe Formation is quarried from the hillside, and black adobe clay is obtained in an open pit in the flat nearby. The clays are mixed in various proportions, molded into brick and tile, and fired in field kilns. The plant east of Montecito is located in Toro Canyon, where plastic weathered clay interbedded with soft yellow sands of the Sespe Formation is used in the manufacture of brick and tile.

Sandstone

The hard sandstone of the Eocene formations, particularly the "Coldwater" Sandstone, was much used in early years as building material, until it was displaced by cement. The Santa Barbara Mission was built of this sandstone, as well as numerous stone walls in Mission Canyon, on Mission Ridge, and in Montecito. Deposits of sandstone are numerous, and there are several old quarries in Mission and Rattlesnake Canyons.

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Exploratory wells on south side of Santa Ynez Range, Goleta quadrangle.

Map no.	T.	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
A 1	5N	30W	36	Barnsdall Oil Company Edwards Estate 1	1927	2720	0 -2720 —Ts
A 2	4N	30W	2	Tidewater Association Oil Edwards Estate 1	1937	2450	0 - 242 —Tr 242 -2450 —Ts
A 3	4N	30W	1	Standard Oil Company Edwards Estate 1	1929	3380	0 - 130 —Tr 130 - 725 —Tv 725 -3380 —Ts
A 4	4N	30W	1	Standard Oil Company Edwards Estate 2	1930	3404	Bottomed in Tg-Tcw
A 5	4N	30W	1	Shell Oil Company Edwards Estate 1	1937	1885	0 - 490 —Tv 490 -1885 —Ts
A 6	4N	30W	2	C. W. Morse Rhode Island Estate 1	1937	1400	Bottomed in TV
A 7	4N	30W	2	La Canada Rhode Island Estate 1		696	0 - 497 —Tr 497 - 696 —Tv
A 8	4N	30W	2	La Canada Rhode Island Estate 2		1395	0 -1256 —Tr 1256 -1395 —Tv
A 9	4N	30W	12	Pacific Western Oil Wiley 1	1929	4338	0 -1000 —Tr 1000 -1385 —Tv 1385 -4338 —Ts
A10	4N	29W	1	Omar McGee Pomatto 1	1929?	2782	0 -2383 —Tr 2383 -2710 —Tv 2710 -2782 —Ts
A11	4N	29W	3	E. J. Miley Goleta 1	1926	5664	0 -3000?—Ts 3000?-5664 —Tcw Discovery well, Goleta oil field
A12	4N	29W	7	Scully and Snyder Cochran 7	1929	4900	0 -2950?—Tm 2950?-4552 —Tr 4552 -4801 —Tv 4801 -4900 —Ts
A13	4N	29W	8	Padre Oil Company Dos Pueblos 1	1930?	4194	0 -3030 —Tm-Tr 3030 -3308 —Tv 3308 -4194 —Ts
A14	4N	29W	9	Elmer Oil Company Wiley 1		4620	0 -4135 —Tm-Tr 4135 -4503 —Tv 4503 -4620 —Ts
A15	4N	29W	10	Shell Oil Company Hollister 1	1929	2824	0 - 12 —Tr 12 - 340 —Tv 340 -2674 —Ts 2674 —fault 2674 -2824 —Tcw
A16	4N	29W	10	Shell Oil Company Hollister 2	1929	3819	0 - 265 —Tr 265 - 655 —Tv 655 -3484 —Ts 3484 -3819 —Tcw
A17	4N	29W	11	Rice-Firestone	1946	3157	0 -1567 —Qoa-Qsb 1567 -3092 —Tm-Tr 3092 -3157 —Tv
A18	4N	29W	13	The Texas Company Bishop A1	1940	4350	0 - 480 —Qoa-Qsb 480 -3306 —Tm-Tr 3306 -3760 —Tv 3760 -4350 —Ts

Exploratory wells on south side of Santa Ynez Range, Goleta quadrangle—Continued.

Map no.	T.	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
A19	4N	29W	13	The Texas Company Bishop A2	1941	3025	2920 -3025 —Tv
A20	4N	29W	13	The Texas Company Bishop A3	1941	3239	0 - 150 —Qoa-Qsb 150 -1477 —Tm 1477 -3122 —Tr 3122 -3239 —Tv
A21	4N	29W	13	Tannehill Storke 1	1930	5554	0 -2200 —Qsb or Tp 2200 -3825 —Tm 3825 -5489 —Tr 5489 -5554 —Tv
A22	4N	29W	14	Elwood Community	1929	5667	0 -1628 —Qoa-Qsb 1628 -2720?—Tm 2720?-4359 —Tr 4359 -5667 —Tv-Ts
A23	4N	29W	14	East Elwood Petroleum Company Bishop-Evans 1	1935	3732	0 -3664 —Tm-Tr 3664 -3732 —Tv
A24	4N	29W	15	Bankline Oil Company Doty 1	1928	4584	1534 -2911 —Tm 3028 -4492 —Tr 4492 -4572 —Tv 4572 -4584 —Ts
A25	4N	29W	15	Barnsdall-Rio Grande Luton-Bell 1	1928	3208	0 -1450 —Tm 1450 -3174 —Tr 3174 -3208 —Tv Discovery well Elwood oil field
A26	4N	29W	23	Barnsdall-Rio Grande Doty 5	1931	5208	0 -3805 —Tm-Tr 3805 -4196 —Tv 4196 -5208 —Ts
A27	4N	29W	23	J. E. O'Donnell Campbell 1	1930?	5488	0 -3962 —Tsq-Tm 3962 -5254 —Tr 5254 -5488 —Tv
A28	4N	29W	23	Cady Oil Company Bishop 1	1930	5600?	0 -3023 —Tsq-Tm 3023 -4213 —Tr 4213 -4780 —Tv 4780 -5600?—Ts
A29	4N	29W	24	Union Oil Company Storke 1	1945	5022	0 - 500 —Qsb or Tp 500 -2200?—Tsq 2200?-2570 —Tm(upper) 2570 -4380 —Tm(lower) 4380 -5022 —Tr
A30	4N	29W	24	Union Oil Company Campbell 1	1945	5076	0 - 250 —Qsb 250 -1630?—Tsq 1630?-2350 —Tm(upper) 2350 -3845 —Tm(lower) 3845 -5076 —Tr
A31	5N	28W	36	W. J. Carter Carter-Prevedello 1	1950	3000	0 -2738 —Ts 2738 -3000 —Tcw
A32	4N	28W	1	Ohio Oil Company Prevedello 1	1946	3267	0 -3200?—Ts 3200?-3267 —Tcw
A33	4N	28W	1	Carrey and Adams Wright 1	1930	2846	0 -2846 —Ts
A34	4N	28W	1	Standard Oil Company Santa Barbara County Hospital	1930?	2472	0 -1655 —Tr 1656 -2074 —Tv 2074 -2472 —Ts?

Exploratory wells on south side of Santa Ynez Range, Goleta quadrangle—Continued.

Map no.	T.	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
A35	4N	28W	3	California Property Incorporated Stevens 1	1930	4005	0 - 985 —Tr 985 -1240 —Tv 1240 -4005 —Ts
A36	4N	28W	7	Southern California Drilling Company Bishop 1	1931	3165	0 -2260 —Tm-Tr 2260 -2475 —Tv 2475 -3165 —Ts
A37	4N	28W	8	Elwood Consolidated Oil Company Calvaletta 1	1930	3430	1772 -base Tr 1772 -2000 —Tv 2000 -3430 —Ts
A38	4N	28W	9	C. F. Simonds Van Dike 1	1938	1005	0 -1005 —Qsb
A39	4N	28W	9	Hastain-Stone (West Elwood Oil Company)	1934	3472	
A40	4N	28W	10	North American Consolidated Oil Company Pinkham 1	1934	2480	0 - 553 —Qsb 553 -2210 —Tm-Tr 2210 -2480 —Tv
A41	4N	28W	10	Nevada-Standard Oil Langman 1	1932	4721	1970 -2898 —Tm 2898 -4442 —Tr 4442 -4692 —Tv 4692 -4721 —Ts
A42	4N	28W	10	Del Mar Oil Company K. Rowe 1	1943	4240	Bottomed in lower Miocene
A43	4N	28W	12	Security Land and Realty County	1942	3290	Bottomed in lower Miocene
A44	4N	28W	15	General Petroleum Corporation More 4 (directed hole)	1939	4757	0 - 680 —Tm 680 -1475 —Qsb? 1475 -2900 —Tm 2900 -4630 —Tr 4630 -4735 —Tv
A45	4N	28W	22	General Petroleum Corporation More 5	1940	4905	0 - 510 —Qsb or Tp 510 -2450 —Tm 2450 -4288 —Tr 4288 -4642 —Tv 4642 -4905 —Ts
A46	4N	28W	16	Ring Oil Company Marian More 1	1930	5570	0 -3250 —Qsb 3250 -4050 —Tm 4050 -5475 —Tr 5475 -5570 —Tv
A47	4N	28W	16	Ohio Oil Company Oakley 1	1931	6187	0 -2880 —Qsb 2880 -3000 —Tm 3000 -3400 —Qsb or Tp 3400 -4398 —Tm 4398 -6136 —Tr 6136 -6187 —Tv
A48	4N	28W	17	Standard Oil Company Chase and Bryce 1	1934	4397	0 -2125 —Tm 2125 -4071 —Tr 4071 -4386 —Tv 4386 -4397 —Ts
A49	4N	28W	18	Doheny and Doheny Storke 1	1928	5540	0 -1650 —Qsb or Tp 1650 -3920 —Tsq-Tm 3920 -5512 —Tr 5512 -5560 —Tv
A50	4N	28W	20	Shell Oil Company Bishop 1	1934	6508	0 -2671 —Tm 2671 -4054 —Tr 4054 -4390 —Tv 4390 -6508 —Ts

Exploratory wells on south side of Santa Ynez Range, Goleta quadrangle—Continued.

Map no.	T	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
A51	4N	28W	21	General Petroleum Corporation More 1	1929	4533	0 -1935 —Tm 1935 -4190 —Tr 4190 -4533 —Tv gas Discovery well, Goleta gas field
A52	4N	28W	21	General Petroleum Corporation More 2	1930	4327	0 -2335 —Tm 2335 -4250 —Tr 4250 -4327 —Tv gas Gas well
A53	4N	28W	21	General Petroleum Corporation More 3	1930	6912	0 -1887 —Tm 1887 -4139 —Tr 4139 -4492 —Tv gas 4492 -6865 —Ts 6865 -6912 —Tcw Gas well
A54	4N	28W	21	Crandall Permit 138 Permit 138	1931	4900	0 -3320 —Tm 3320 -4584 —Tr 4584 -4900 —Tv
A55	4N	27W	19	G. W. Johnson (Exeter Oil Company) Duncan 1	1935	4062	0 - 200?—Tm 200?-1640 —Tr 1640 -1900?—Tv 1900?-4062 —Ts
A56	4N	27W	19	Bankline Oil Company Duncan Ranch 1	1929	4283	0 -1700?—Tm 1700?-3288 —Tr 3288 -3515 —Tv 3515 -4283 —Ts

Exploratory wells on south side of Santa Ynez Range, Santa Barbara and Carpinteria quadrangles.

Map no.	T.	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
B 1	4N	27W	17	Samarkand Hotel (water well)	1938	585	170 – 370 —Qsb 385 – 585 —Ts?
B 2	4N	27W	20	Petroleum Exploration Company McWilliams 1	1929	3421	0 –2145 —Qsb 2145 –2598 —Ts 2598 –3421 —Tcw
B 3	4N	27W	20	Channel Development Company Pinkerton 1	1936	6302	0 –1200?—Tr 1200?–1480?—Tv 1480?–5500?—Ts 5500?–6302 —Tcw
B 4	4N	27W	20	M. Humphries Edna Mae 1	1936	1600	Bottomed in Tv
B 5	4N	27W	21	Dralock Oil Company Beckstead 1	1930?	1555	1429 –1462 —Tv 1462 –1555 —Ts
B 6	4N	27W	27	D A Hargrave	1930	3552	0 –1900?—Tm–Tr 1900?–2200?—Tv 2200?–3552 —Ts
B 7	4N	27W	28	Richfield Oil Corporation M'Divani 1	1952	9988	0 –2070 —Tm–Tr 2070 –2341 —Tv 2341 –9988 —Ts (60–85 dips below 4200)
B 8	4N	27W	28	Olympic Oil Company Knott 1	1929	2460	0 –2175 —Tm–Tr 2175 –2460 —Tv
B 9	4N	27W	28	Scott-McIntosh Caldwell 1	1930?	2625	1759 –1874 —Tv 1874 –2625 —Ts
B10	4N	27W	29	Olympic Refining Company Community 1	1929	2410	0 –2152 —Tm–Tr 2152 –2410 —Tv oil Discovery well, Palisades Mesa oil field
B11	4N	27W	30	Lincoln Drilling Company Medzikhousky 1	1929	2434	0 –1200?—Tm 1200?–2370 —Tr 2370 –2434 —Tv
B12	4N	26W	15	Finnell Williams 1		3410	0 –1505 —Tr 1505 –1592 —Tv 1592 –3410 —Ts
B13	4N	26W	16	Dietzmann Williams 1	1935?	4582	0 – 629 —Tr 629 –1100 —Tv 1100 –4582 —Ts
B14	4N	26W	16	Adobe Hill Oil Company Adobe 1	1953	4630	932 –1240 —Tv 1240 –4630 —Ts
B15	4N	26W	16	Vista Del Mar Oil Company Williams 1	1935?	4126	0 – 815 —Qc 815 – 990 —Tr 990 –1564 —Tv 1564 –4126 —Ts
B16	4N	26W	22	Getty Becker 1	1929	5041	0 – 110 —Qc 110 –2254 —Tr 2254 –2713 —Tv 2713 –5041 —Ts
B17	4N	26W	23	Loon Point Oil Company Bailard 1	1948	2602	0 – 400?—Qc–Qsb 400?–2227 —Tr 2227 –2602 —Tv
B18	4N	26W	23	Loon Point Oil Company Bailard 2	1949	2649	0 – 415 —Qc–Qsb 415 –2470 —Tr 2470 –2649 —Tv

Exploratory wells on south side of Santa Ynez Range, Santa Barbara and Carpinteria quadrangles—Continued

Map no.	T.	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
B19	4N	25W	18	Shell Oil Company Fithian 1	1930	4389	0 – 378 —Ts 378 –1433 —Tcw ss 1433 –1930 —Tcw ss–sh 1930 –4174 —Tcd 4174 –4389 —Tma
B20	4N	25W	29	Santa Barbara Oil and Gas Company Bryce 1	1935?	2567	0 – 640 —Qa & Qoa 640 –2005 —Qc 2005 –2569 —Qsb
B21	4N	25W	29	Santa Barbara Oil and Gas Company Santa Barbara 1	1936	2650	
B22	4N	25W	29	Western Oil Royalties Limited Bryce 1	1939	2023	0 – 357 —Qa 357 –1668 —Qc 1668 –2023 —Qsb
B23	4N	25W	30	Western Gulf Oil Company Bryce 1	1945	3639	0 –3443 —Qa, Qoa, Qc, Qsb 3443 –3639 —Ts
						3930 (redrill to south)	0 –3930 —Qa, Qoa, Qc, and Qsb
B24	4N	25W	32	Carpinteria Oil Company Carpinteria	1942	3414	0 –3000 —Tr 3000 –3414 —Qsb
B25	4N	25W	33	Nugent Oil Company	1930?	3678	0 – 40 —Tm 40 –3678 —Tr
B26	4N	25W	33	Continental Oil Company Bailard 1	1929	4535	0 –1900± –Tm 1900± –4535 —Tr
B27	4N	25W	33	Continental Oil Company Franklin 1	1930	4169	0 –1700± —Tr 1700± –4169 —Tr
B28	4N	25W	33	Continental Oil Company State permit 124	1930	5735	0 –3270 —Tm 3270 –5735 —Tr
B29	4N	25W	33	The Texas Company Carpinteria Community 1	1932	4208	0 – 708 —Qc? 708 –1714 —Tr 1714 –4141 —Qc–Qsb 4141 –4208 —Ts?

Exploratory test wells on north side of Santa Ynez Range, San Rafael Mountains quadrangle.

Map no.	T.	R.	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
C 1	6N	30W	13	Shell Oil Company Barrett 1	1939	1956	0 -1100?—Tm(upper) 1100?-1452?—Tm(lower) 1452?-1591 —Eocene 1591 -1956 —conglom.
C 2	6N	29W	19	Richfield Oil Corporation San Marcos 1	1939	1961	0 - 287 —Tm(upper) 287 -1585 —Tm(lower) 1585 -1658 —Tt 1658 -1913 —Tcd? sh 1913 -1961 —Tma? ss
C 3	6N	29W	19	Richfield Oil Corporation San Marcos 2	1939	3600	0 - 410 —Tm(upper) 410 -1900 —Tm(lower) 1900 -2012 —Tt 2012 -2110 —Tcd? sh 2110 -2770 —Tma? ss 2770 -3600 —Tj sh
C 4	6N	29W	19	Richfield Oil Corporation San Marcos 3	1939	2500	0 - 310 —Tm(upper) 310 -1490 —Tm(lower) 1490 -1700 —Tt 1700 -2030 —Tcd? sh 2030 -2330 —conglom. 2330 -2500 —Tma? ss
C 5	6N	29W	29	L. W. Welch Welch-Janeway 3	1950	6106	0 -2048 —Tm(upper) 2048 -2770 —Tm(lower) 2770 -2175 —Tt? 2175 -4220 —Tr & Tv(?) 4220 -5440 —Ts? conglom. 5440 -6106 —Tcw-Tcd(?)
C 6	6N	28W	19	F. W. Manning Lazy R G 1	1948	4858	0 -1920 —Qpr 1920 -2018 —Tca 2018 -4675 —Tm(upper) 4675 -4858 —Tm(lower)
C 7	6N	28W	19	L. W. Welch Lazy R G 2	1950	6636	0 -2145 —Qpr 2145 -2205 —Tca 2205 -5145 —Tm(upper) 5145 -5847 —Tm(lower) 5847 -6636 —Ke(Knoxville)
C 8	5N	30W	1	Ohio Oil Company Santa Ynez Unit 1	1949	6922	0 -3000 —Kj 3000 -4409 —Tg-Tcw ss 4409 -6222 —Tcd sh 6222 -6916 —Tma ss 6916 -6922 —Tj sh
C 9	5N	29W	6	British American Petroleum Company and Ohio Oil Company Santa Ynez Unit 2	1950	2629	0 - 150 —Kj 150 - 500 —Tv or Ts? 500 -2268 —Tcw 2268 -2629 —Tcd
C10	5N	29W	5	British American Petroleum Company and Ohio Oil Company Santa Ynez Unit 3	1951	4002	200?-1050 —Tcw or Tg? ss 1050 -2881 —Tg? & Tsa sh 2881 -3684 —Tcd? sh 3684 -4002 —Tma? ss
C11	5N	29W	5	British American Petroleum Company and Ohio Oil Company Santa Ynez Unit 4	1952	4507	0 - 920 —Kj 920 - 970 —fault zone 970 -1985 —Tcw 1985 -3640 —Tcd 3640 -4507 —Tma
C12	7N	29W	3	San Marcos Oil Syndicate Elliot No. 1	1927	3631	0 -1400 —Qpr 1400 -1560 —Tca 1560 -1960 —Tsq 1960 -3050 —Tm 3050 -3300 —Tm chert 3300 -3390 —Tml 3390 -3631 —sp

Exploratory test wells on north side of Santa Ynez Range, San Rafael Mountains quadrangle—Continued.

Map no.	T.	R	Sec.	Name of company and test well	Year drilled	Depth (feet)	Geology
C13	7N	29W	33	The Texas Company Fulwider No. 1	1951	3486	0 -1340 —Tpr & Tca 1340 -1600±—Tsq 1600 -3475 —Tm 3475 -3486 —sp
				Little Pine Mountain quadrangle			
D 1	5N	27W	14	Pacific Western Oil Company Gibraltar Dam 1	1930	2314	0 - 250?—Tt-Tv 250?-2314 —Ts

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EXPLANATION

QUATERNARY

Recent

Qal
Alluvium

Qls
Landslide

Pleistocene

Qoa
Older alluvium
Dissected terraces of unconsolidated stream deposits

Qfg
Fanglomerate
Boulder, cobble and pebble deposits of valley fill and old dissected fans

Qc
Casitas Formation
Gravels, sands, and clays; non-marine

Qsb
Santa Barbara Formation
Fossiliferous sand and silts; marine

Pliocene

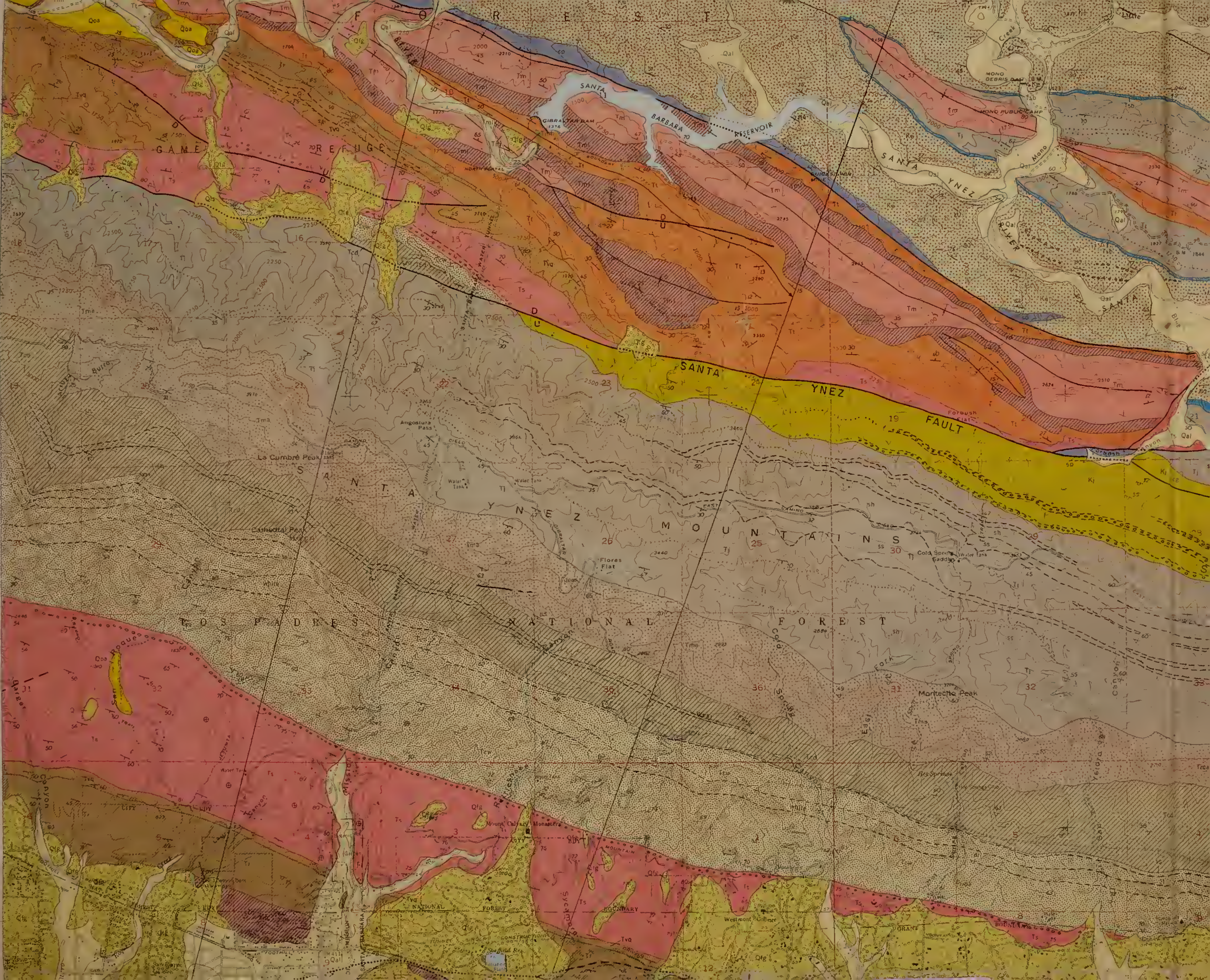
Tsq
Sisquoc Formation
Shown in cross section only

Miocene

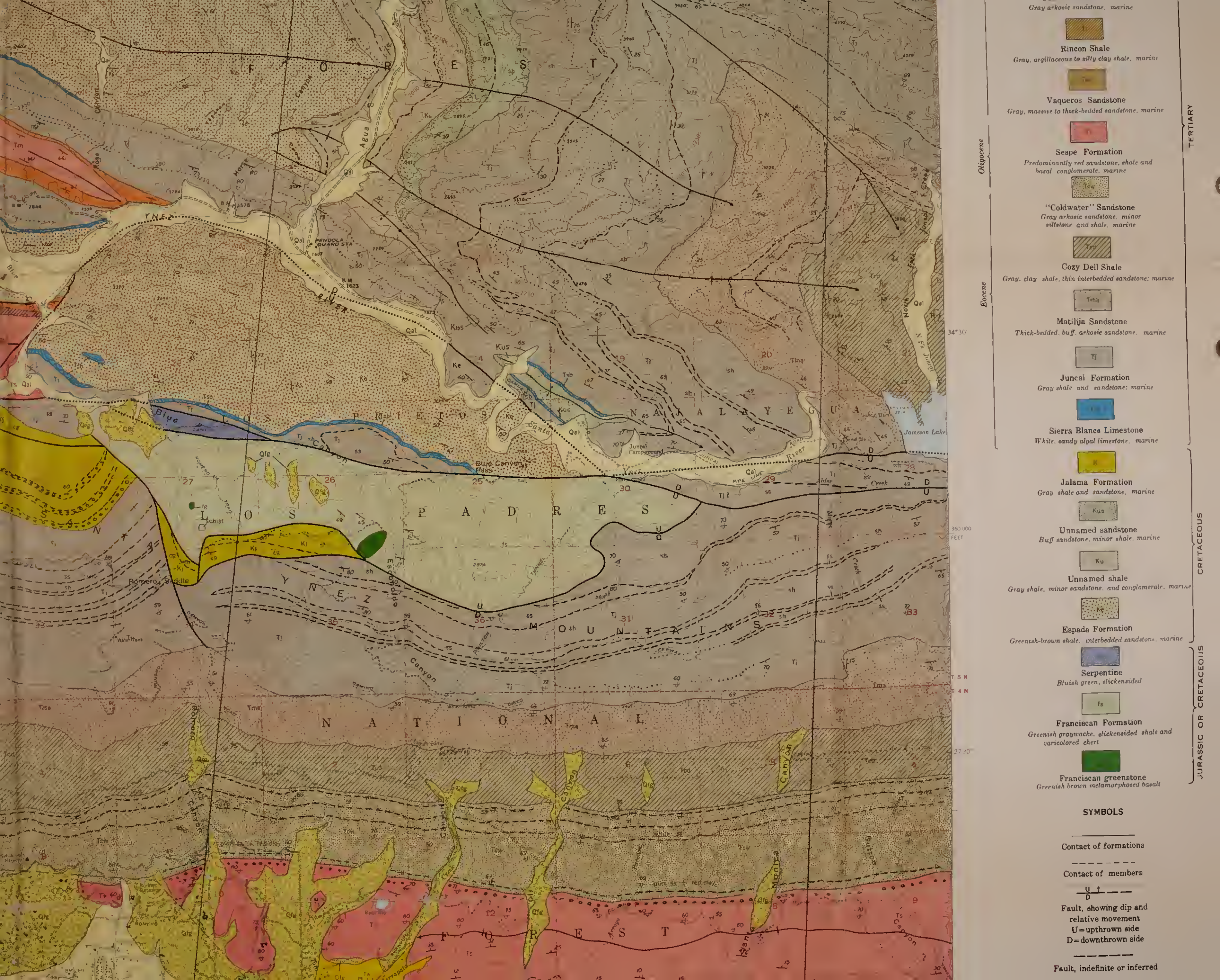
Tm
Monterey Shale — upper
Hard, platy silicious shale; marine

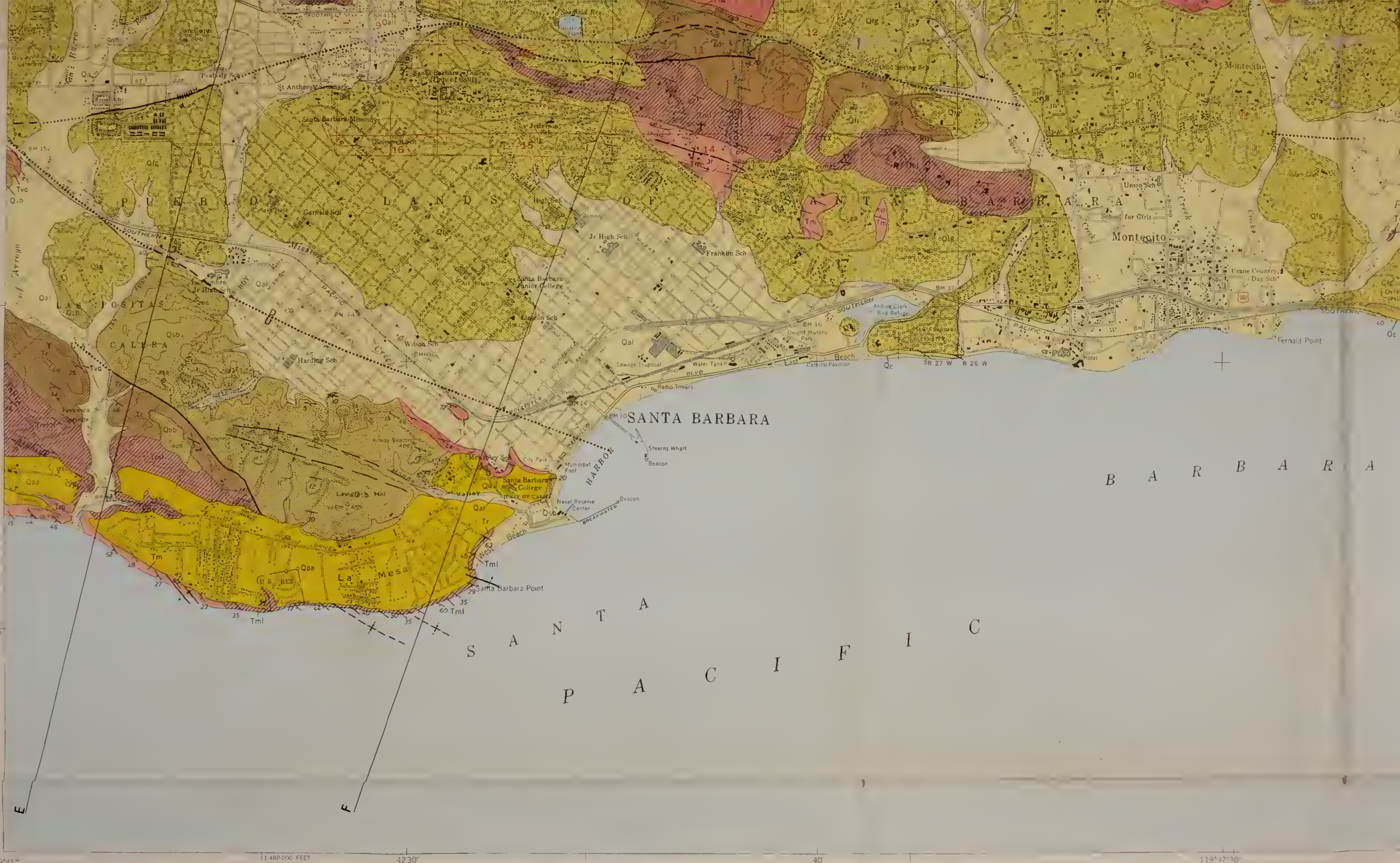
Tml
Monterey Shale — lower
Soft, brown organic shale; marine

Tt



34°30'
27'30"
T 5 N
T 4 N
FOREST
SANTA BARBARA RESERVOIR
GIBRALTAR DAM
MONO DEBRIS DAM
MONO PUBLIC CAMP
SANTA YNEZ RIVER
GAME REFUGE
SANTA YNEZ FAULT
Forbush Flat
SANTA YNEZ MOUNTAINS
Angostura Pass
La Cumbre Peak
Cathedral Peak
Flores Flat
Cold Spring Saddle
LOS PADRES NATIONAL FOREST
Montecito Peak
Mount Calvary Monastery
Westmont College


Gray arkosic sandstone, marine
Rincon Shale
Gray, argillaceous to silty clay shale, marine
Vaqueros Sandstone
Gray, massive to thick-bedded sandstone, marine
Sespe Formation
Predominantly red sandstone, shale and basal conglomerate, marine
"Coldwater" Sandstone
Gray arkosic sandstone, minor siltstone and shale, marine
Cozy Dell Shale
Gray, clay shale, thin interbedded sandstone; marine
Matilija Sandstone
Thick-bedded, buff, arkosic sandstone, marine
Juncal Formation
Gray shale and sandstone; marine
Sierra Blanca Limestone
White, sandy algal limestone, marine
Jalama Formation
Gray shale and sandstone, marine
Unnamed sandstone
Buff sandstone, minor shale, marine
Unnamed shale
Gray shale, minor sandstone, and conglomerate, marine
Espada Formation
Greenish-brown shale, interbedded sandstone, marine
Serpentine
Bluish green, slickensided
Franciscan Formation
Greenish graywacke, slickensided shale and varicolored chert
Franciscan greenstone
Greenish brown metamorphosed basalt
Oligocene
Eocene
TERTIARY
CRETACEOUS
JURASSIC OR CRETACEOUS
SYMBOLS
Contact of formations
Contact of members
Fault, showing dip and relative movement
U=upthrown side
D=downthrown side
Fault, indefinite or inferred
LOS PADRES NATIONAL FOREST
SANTA YNEZ MOUNTAINS
Jameson Lake
Blue Canyon Pass
Romero Saddle
Juncal Campground
34°30'
T 5 N
T 4 N



BASE MAP

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Edited and published by the U. S. Geological Survey

16°

TRUE NORTH

MAGNETIC NORTH

APPROXIMATE MEAN DECLINATION, 1952

GEOLOGIC MAP OF THE LITTLE PINE MOUNTAIN, HILDRETH PEAK, S… CARPINTERIA 7½ – MINUTE QUADR… SANTA BARBARA COUNTY, CALI…

By T. W. Dibblee, Jr.

Scale $\frac{1}{31680}$

1 ½ 0 1 Mile

1000 500 0 1000 2000 Yards

CONTOUR INTERVAL 50 FEET
DATUM IS 1929 MEAN SEA LEVEL

1966

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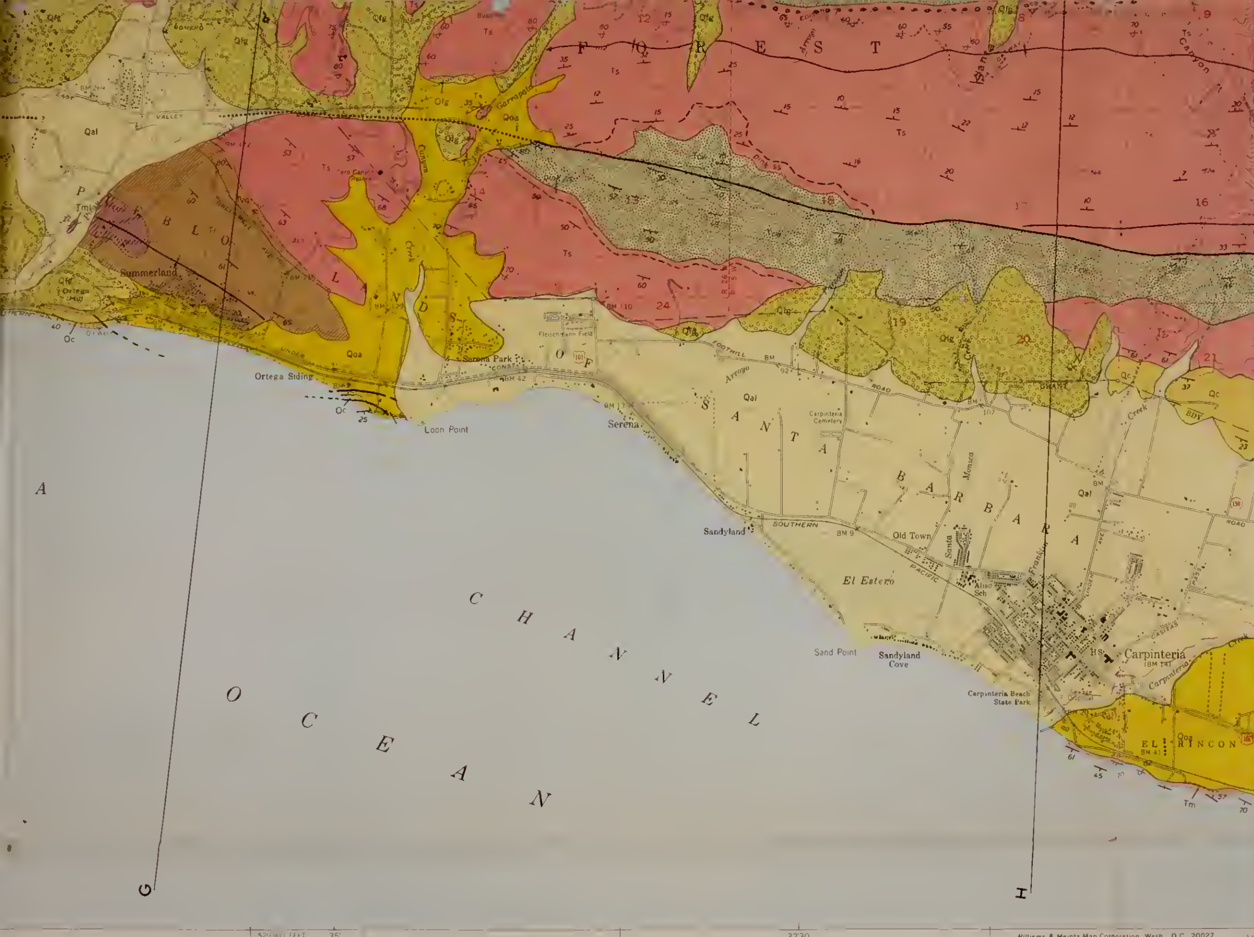

Fault, showing dip and relative movement
U = upthrown side
D = downthrown side

Fault, indefinite or inferred

Fault, concealed

Anticline showing plunge

Syncline showing plunge

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

Horizontal beds

Sandstone

Conglomerate

sh = shale   st = siltstone
ls = limestone

LOCATION OF QUADRANGLES

Geology by T. W. Dibblee, Jr., 1931-38, 1952, 1963

THE
K, SANTA BARBARA, AND
UADRANGLES
CALIFORNIA

LOCATION OF MAP AREA

1 Mile

2000 Yards

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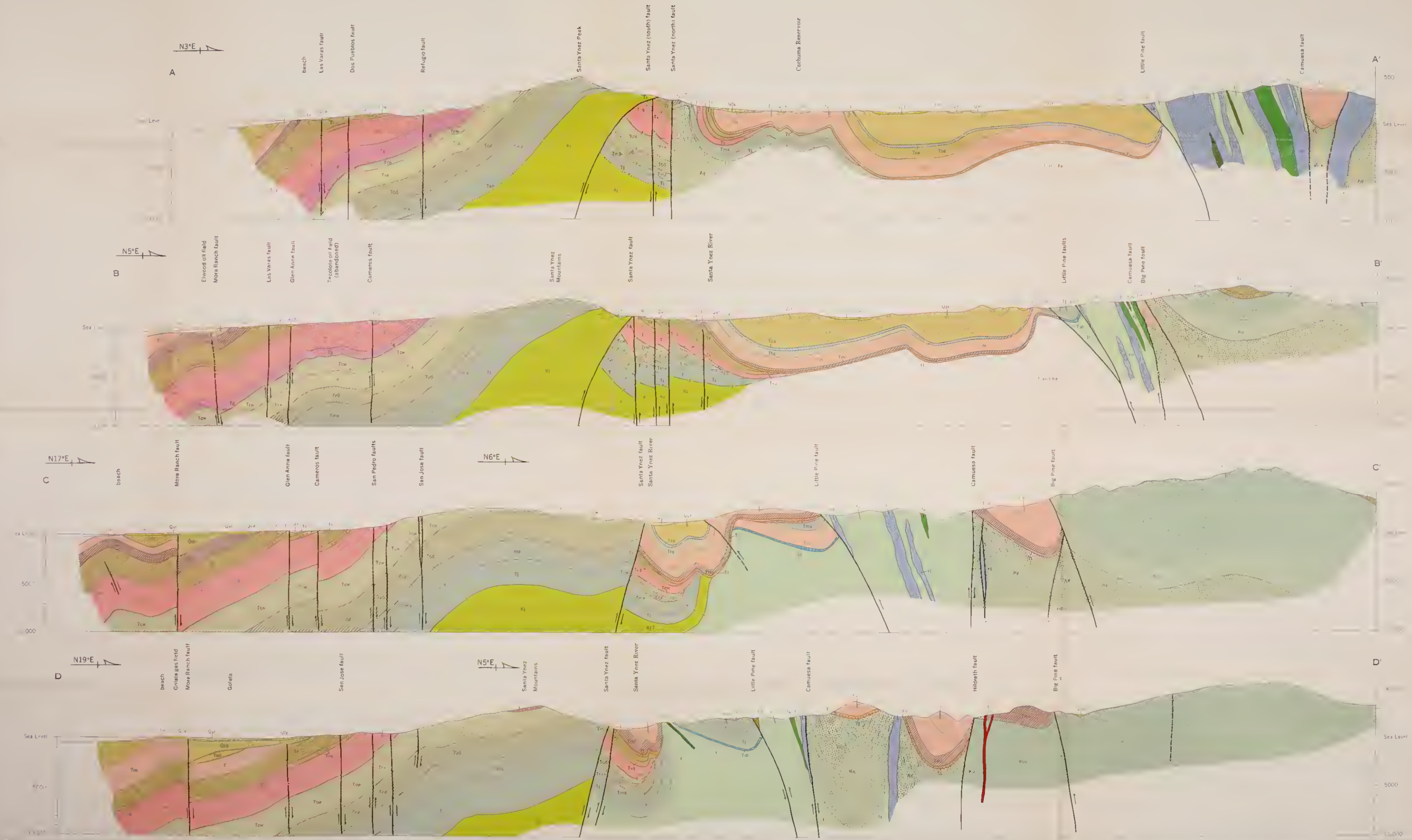

STRUCTURE SECTIONS ACROSS THE GOLETA AND SAN RAFAEL MTN. 15-MINUTE QUADRANGLES, SANTA BARBARA COUNTY, CALIFORNIA

By

T. W. Dibblee, Jr.

Horizontal and vertical scale

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EXPLANATION

QUATERNARY
- RECENT
  - Alluvium
  - Landslide rubble
- PLEISTOCENE
  - Older alluvium
  - Fanglomerate
  - Paso Robles Formation
  - Santa Barbara Formation

TERTIARY
- PLIOCENE
  - Pico Formation
  - Carraga Sandstone
  - Tequepis Sandstone
  - Sisquoc Formation
- Basalt dikes
- MIOCENE
  - Monterey Shale upper
  - Monterey Shale lower
  - "Temblor" sandstone
  - Rincon Shale
  - Vaqueros Sandstone
- OLIGOCENE
  - Sespe Formation
  - Gaviota Sandstone
- EOCENE
  - "Coldwater" sandstone
  - Sacate Formation
  - Cozy Dell Shale
  - Matilija Sandstone
  - Anita Shale
  - Juncal Formation
  - Sierra Blanca Limestone

CRETACEOUS
- Jalama Formation
- Unnamed sandstone
- Unnamed shale
- Unnamed conglomerate
- Espada Formation
- Serpentine

JURASSIC OR CRETACEOUS
- Franciscan sandstone or graywacke and shale
- Franciscan shale
- Franciscan chert
- Franciscan greenstone

Franciscan undifferentiated shown on cross section only

SYMBOLS

Contact of formations

Contact of members

Fault, showing dip and relative movement
U, upthrown side
D, downthrown side

Fault, indefinite or inferred
dotted where concealed

Anticline showing plunge

Syncline showing plunge

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

Horizontal beds

Sand

Conglomerate

sh = shale st = siltstone

Mercury prospect

Mercury mine

Dry hole

BASE MAP
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GEOLOGIC MAP OF THE GOLETA AND SAN RAFAEL MTN. 15-MINUTE QUADRANGLES, SANTA BARBARA COUNTY, CALIFORNIA

By
T. W. Dibblee, Jr.

Scale 1:62,500

1966

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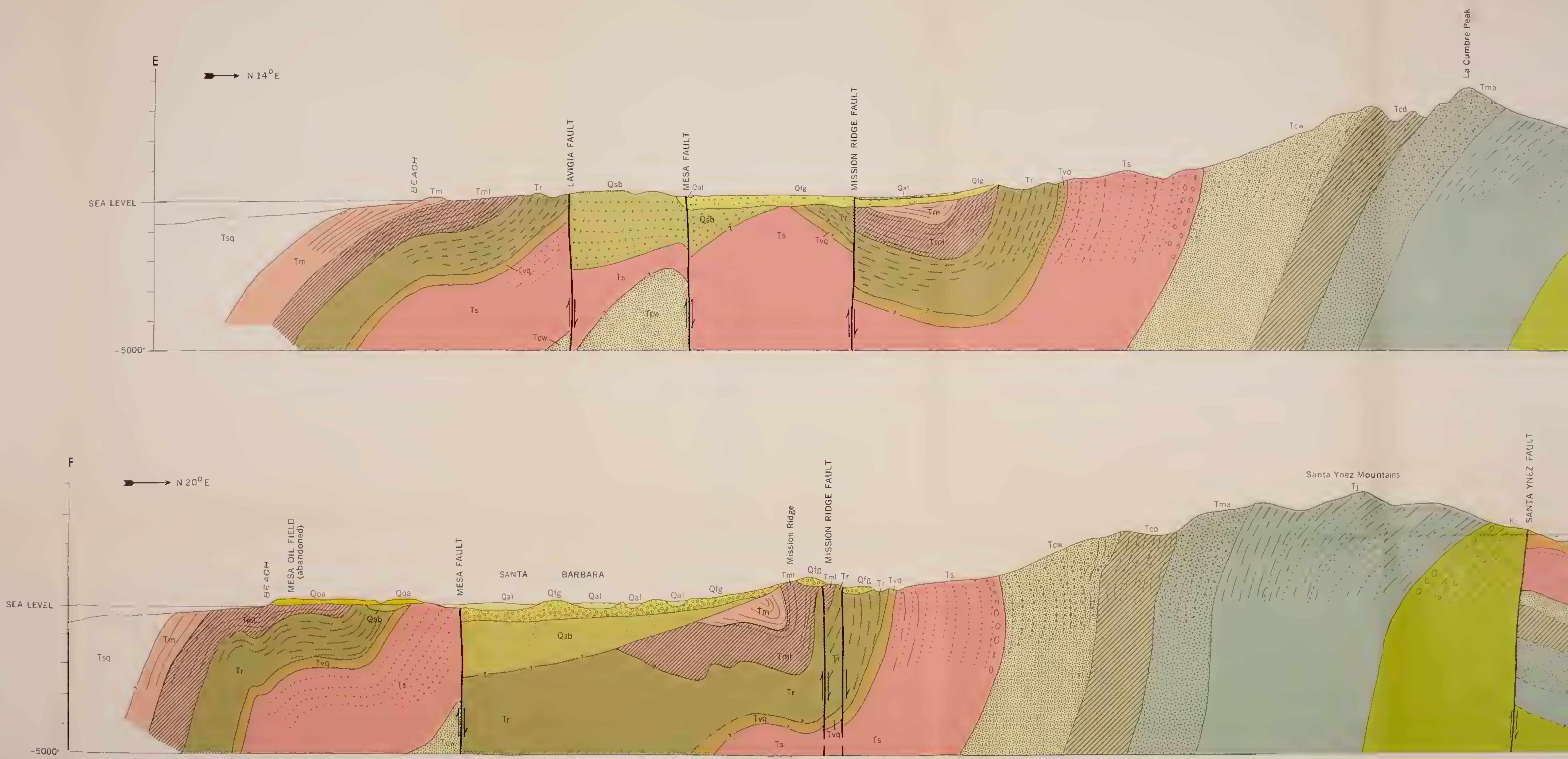
E
N 14° E
SEA LEVEL
-5000'
BEACH
LAVIGIA FAULT
MESA FAULT
MISSION RIDGE FAULT
La Cumbre Peak
Tsq
Tm
Tml
Tr
Tvq
Ts
Tcw
Qsb
Qal
Qfg
Tcd
Tma
F
N 20° E
BEACH
MESA OIL FIELD
(abandoned)
MESA FAULT
SANTA BARBARA
Mission Ridge
MISSION RIDGE FAULT
Santa Ynez Mountains
SANTA YNEZ FAULT
Qoa
Tj
Kj

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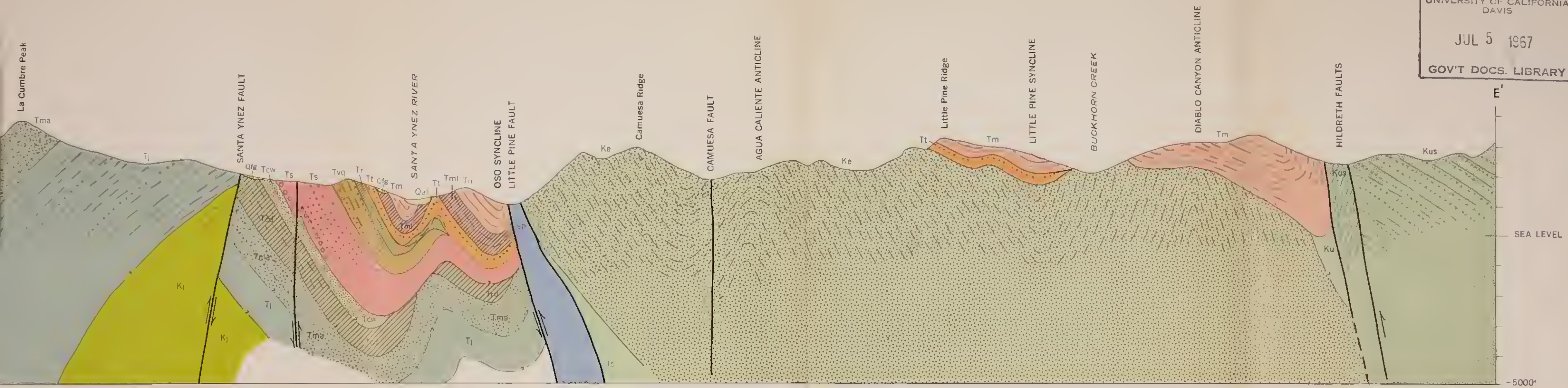

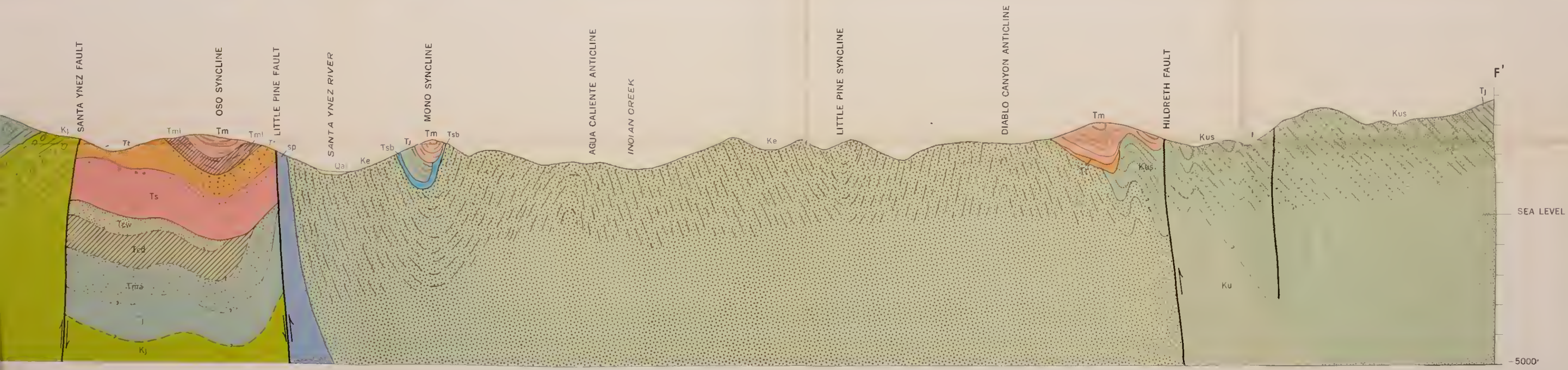

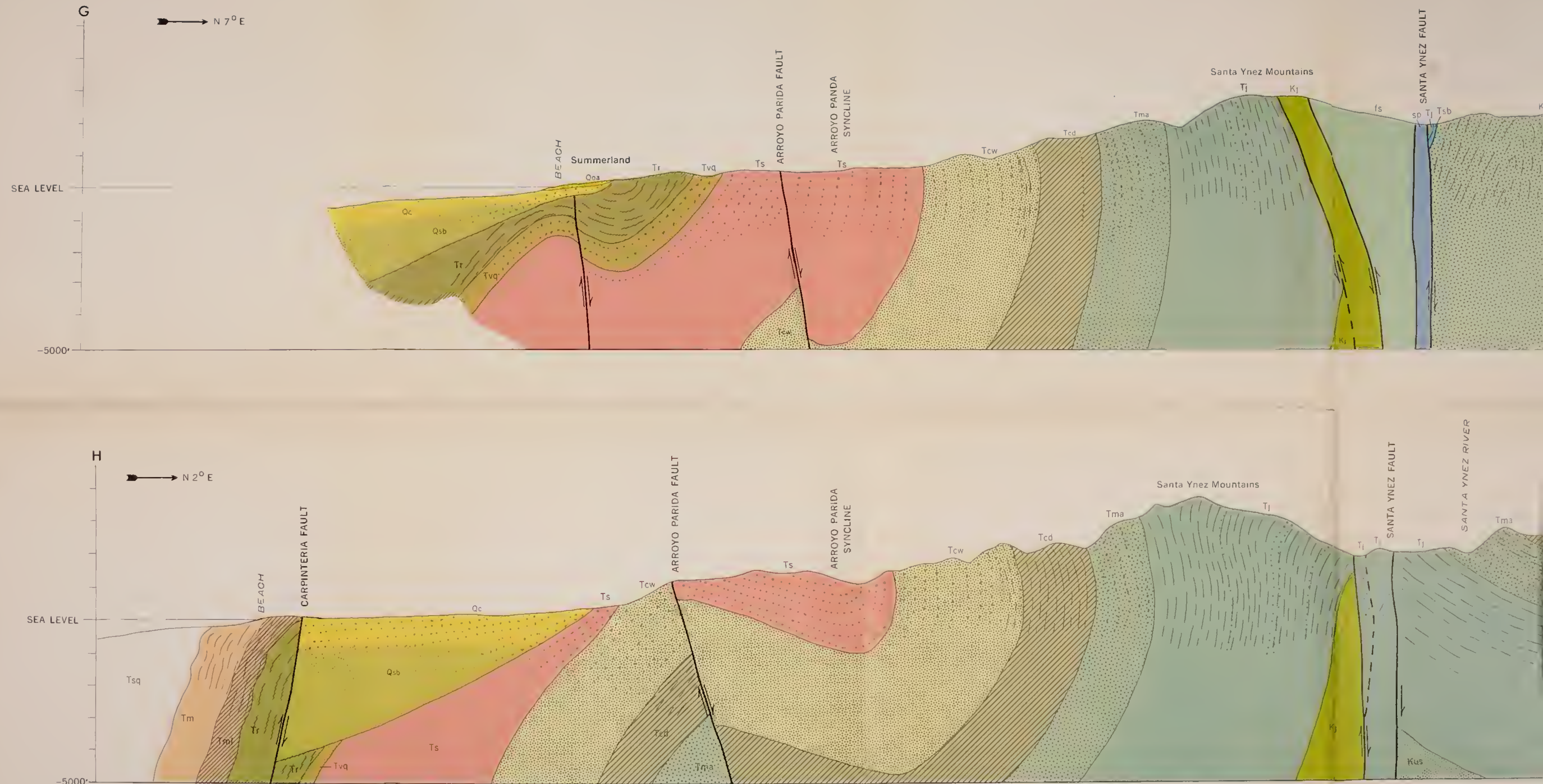

STRUCTURE SECTIONS ACROSS THE LITTLE PINE MOUNTAIN, HILDRETH PEAK, SANTA BARBARA, A

By T. W. Dibblee, Jr.

Scale $\frac{1}{31680}$

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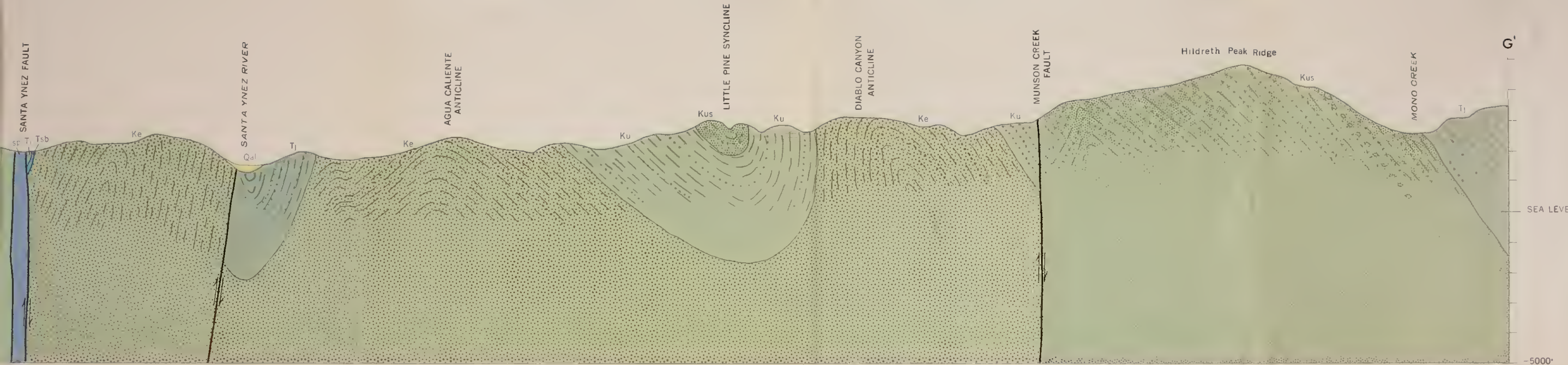

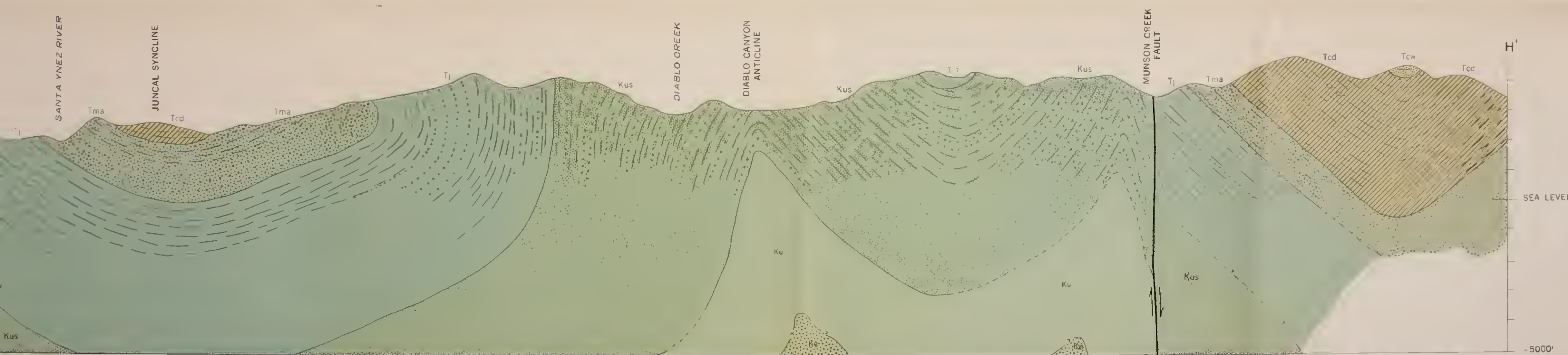

ARBARA, AND CARPINTERIA 7½ – MINUTE QUADRANGLES, SANTA BARBARA COUNTY, CALIFORNIA

By T. W. Dibblee, Jr.

Scale $\frac{1}{31680}$

0 1 Mile

0 1000 2000 Yards

(SEE PLATE 1)